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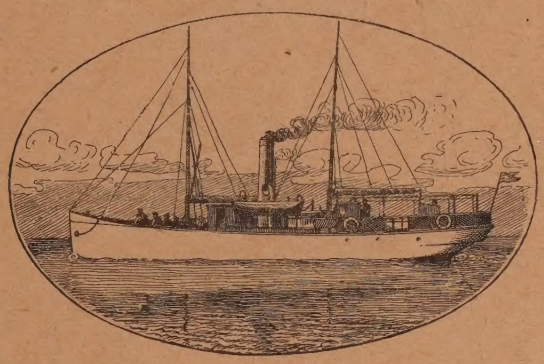

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1915.

By

C. G. Joh. Petersen,
Ph. D., L. L. D.
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Copenhagen.
I Commission hos G. E. C. Gad.
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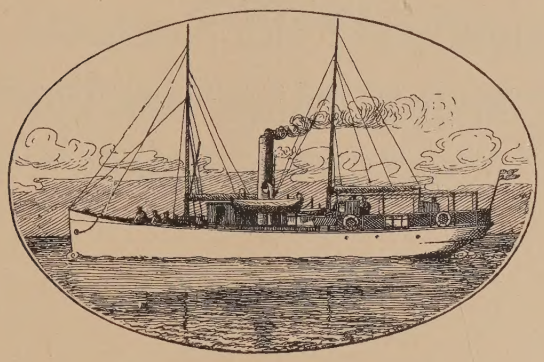

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On the Animal Communities of the Sea Bottom in the Skagerak, the Christiania Fjord and the Danish waters.

(with one Chart and four Tables.)

by

C. G. Joh. Petersen.

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In Report XXI, I described and charted the Danish Animal Communities of the Sea Bottom, particularly in the Waters inside the Skaw, and in Report XXII, I further sketched, from a study of other works on the subject, the probable distribution of these animal communities outside Denmark, suggesting also, that other communities might yet be found to exist both in deeper water and outside the seas nearest the Danish waters. This being accomplished, I was then most anxious to personally investigate, by means of the bottom sampler, the actual conditions as regards the animal communities in the deep waters nearest to our coasts, the Skagerak and the Christiania Fjord. Given favourable weather, this could be done in a short time with the small steamer »Sallingsund« belonging to the Station, the only additional requisites being a longer 5 mm wire, and further weighting of the bottom sampler itself. Save for these items, everything was ready for the cruise.

Such investigations were therefore included in the Station's plan of work for 1914, and approved by the Ministry. I had originally obtained permission to make the cruise outside the actual Danish waters on board the steam lifeboat »Vestkysten«; it was found, however, that the use of this vessel would involve some difficulty in hauling in the wire with sufficient rapidity. I therefore ventured to make the cruise on board the »Sallingsund«, and had the good fortune to encounter most favourable weather, especially at such places where this was indispendable for the working of the vessel, which had been built for work in the Limfjord only.

Dr. Johan Hjort, Director of Fisheries for Norway, procured the necessary permission from the Norwegian Government for investigation of the territorial waters in question, and was present on board during that part of the cruise.

The voyage commenced at midnight on the 23rd of June. We sailed from Elsinore to Marstrand, arriving at the Swedish zoological station of Kristineberg at Fiskebäkskil (near Lysekil). Here we stayed for several days, making investigations among the reefs and in the fjords, with the assistance of Professor H. Théel, Dr. H. Østergreen, and the Fiskeriintendent, Dr. K. A. Andersson. On the 1st July, Dr. Johan Hjort came on board, and sailed with us the next

day to the Christiania Fjord, leaving us at Sandefjord on the 11th July. On the 12th July, valuations were made in the deepest part of the Skagerak from 3 o'clock in the morning; at 6.30 p. m. the same day we arrived in harbour at the Skaw.

There were three points which I was particularly anxious to investigate in the course of his cruise: in the first place, how the bottom sampler might work — in purely technical respects — in deep water, at about 700 metres; secondly, how far animal communities similar to our own might be found at corresponding depths in the deep Norwegian waters; and finally, what the deep water might have to show in the form of animal communities unlike those found in our shallower regions.

I had already, on some few occasions, been out in water of 200—300 metres depth, but had encountered difficulties owing to the fact that the swell, and the movement of the vessel, caused the bottom sampler to close before reaching the bottom. This easily happens when the line slacks, and may even be occasioned by letting the wire run out too fast. Premature closing of the apparatus was here guarded against by a parachute contrivance in the form of a bag fixed above the implement, the effect of this being to induce an even velocity of descent, unaffected by any slacking of the line above. The apparatus now worked satisfactorily, the only further requirement being the fastening of additional weights to the implement when working at extreme depths, in order to render the grounding perceptible, the increased weight of wire out in deep water necessitating a corresponding increase in the weight of the bottom sampler itself. A small bottom sampler, $0._1$ m^2, was used in deep water and at extreme depths; the results obtained afford, in my opinion, sufficient proof that such an implement may well be used at even greater depths, working with perfect ease from a small rapid winch. A 5 mm wire will be heavy enough for considerable depths; in our case, at least, it was found sufficient for work between 600—700 metres. As to what depth can be reached, this will naturally depend on the strength and weight of the wire, and on the weight required for sinking the bottom sampler; the question may best be solved by further experiment. I am, however, inclined to think that samples taken with this apparatus will be found very poor as regards animal content when working at very great depths; even in the Skagerak, at its deepest part, the number of animals per $0._1$ m^2 was very slight *(vide infra)**)

As regards the investigations made, I may here remark that the points of observation — some 52 stations in the Christiania Fjord and about 14 in the Skagerak — were too few in number to furnish any adequate basis for charting the distribution of the animal communities found; a »landscape« of so irregular formation as the bottom of the Christiania Fjord would demand numerous investigations before this could be done.

*) Professor Théel showed me some bottom samplers — called in Swedish »Bottenhuggare« — of a very different construction, preserved at the station at Kristineberg; they had been used by Lovén, Torell and Nordenskiöld. Their span was, however, very slight; they were held open by two cannon balls, which were released when the apparatus touched bottom, whereupon closing was effected by means of a spring. Very little appears to have been written as to these bottom samplers; they have, however, been used, which in itself indicates that the investigators in question were dissatisfied with the results obtained by dredge alone.

It was not, moreover, my intention to make any such survey, even in the Skagerak, which generally presents but little difficulty in this respect, provided one keeps clear of the coasts. My idea was rather to study the composition of the animal communities, and to ascertain what communities were to be found in the waters in question. Even this plan, however, required some limitation, as I was well aware that the communities of the rocky bottom are difficult to investigate quantitatively with the bottom sampler; it was thus only the animal communities of the level bottom which were subjected to investigation. I had already on a previous occasion, in 1897, worked in the Christiania Fjord, with Dr. Hjort, using implements designed to tow on the bottom, and was thus aware that large areas of the same were covered with clay, consequently presenting a level surface well suited to investigation with the bottom sampler. The Norwegian charts, moreover, furnished excellent information, and I had therefore no hesitation in commencing an investigation of the communities of the sea bottom in a country where corresponding investigations on land would have been practically impossible; in other words, I knew that the bottom of the fjord was covered with loose earths to a far greater extent than was the case with the adjacent land. Only 5 stations were found to have been ill-chosen; i. e. on rock or stony bottom, these being No. 24, some way up beyond Dröbak, and Nos. 6, 7, 52 and 46 near the Skaw.

In cases where the investigator cannot, or does not wish to chart the communities of a given water, there is practically only one other method of studying them; *viz.* by taking profiles of the water through all depths. The animal communities of any water will always be found to group themselves according to depth; when therefore samples are taken at all depths from the coast outwards, preferably in a straight line, the results will give an idea of every community in the water in question, save perhaps for some few of purely local character. This method is easily practicable in our waters, where the slope of the bottom is more or less regular and even; in the Christiania Fjord, however, with its steep slopes and rocky grounds, true profiles are difficult to obtain. In some places, only the shallow water can be worked, in others only the deepest parts, while for intermediate depths a third locality must be chosen.

The stations marked on the accompanying chart will therefore be found to exhibit a certain irregularity of position; on comparing the station lists of fauna, however, arranged either according to depth or according to animal contents, — both methods give almost the same result — some sort of profile of the communities will nevertheless be obtained. I have been obliged to pursue this method in the case of the Christiania Fjord, and found it advisable, for practical reasons, to adopt a somewhat similar method in the Skagerak. The method in question affords a far more comprehensive view of the whole, without, as far as I can see, in any way impairing the accuracy of the results.

Profiles I—III show the whole of the material from the Christiania Fjord and the Skagerak in detail, with the exception of the 5 less successful stations on rocky ground, the Horten profile Nr. 36, and finally Nr. 30, which will be referred to later on. The position of the stations, with further notes as to depth, nature of bottom, etc., will be found in the lists appended, pp. 23—26. The stations up beyond

Drøbak together form Profile III, those outside Drøbak Profile II; the depth limits for the communities do not appear to be altogether identical in both waters.

With a view to testing this profile method as a whole, and rapidly becoming acquainted with the conditions in the Christiania Fjord generally, I spent one afternoon taking a profile at Horten, where the nature of the bottom affords an excellent opportunity for more or less accurate work. The usual characteristic species were at once determined on board, as far as possible, and noted down. This profile is shown on p. 11.

This preliminary method, with one or very few bottom samples at the separate stations, at once gave me the impression that the shallower parts of the Christiania Fjord exhibited the same communities which I knew from Danish waters, with the addition of one or two others in deeper water. Before proceeding to further discussion of this point, however, I should perhaps make some few observations on the classification and terminology of animal communities in general.

The work already accomplished in this sphere, both in our own and deeper waters, has in course of time shown, that a series of species characterise the various communities, *i. e.* they compose a very large proportion of the total animal weight, and often moreover, form the greater part of the total number per unit of area. Owing to the difficulty of specific determination in the case of the annelids and certain others of the smaller animals, these are not, as a rule, included among the characteristic species. It has further been found that certain animals of high numerical frequency per 1 m^2 may be found at greatly varying depths and in very different communities; on account of their relatively high numerical value, they may often claim, despite their insignificant size, a considerable proportion of the total weight. These animals may be regarded as attendant species, not as characteristic species. Among such attendant species may be mentioned *Axinus flexuosus, Abra nitida, Nucula tenuis, Corbula gibba,* etc. As to how far these really are good species, or may subsequently be subdivided into others, nothing can at present be said.

It was these investigations in a more extended field which first drew my attention to this occurrence of attendant forms.

In order to indicate the communities to which the different stations belong, I have had recourse to a system of letters or abbreviations, generally referring to one or other characteristic species; they are as follows:

Echinoderms.		Bivalves.	
B.	*Brissopsis Lyrifera.*	d.	*Macoma baltica* etc.
E.	*Echinocardium cordatum.*	v.	*Venus gallina & Tellina fabula* etc.
Fil.	*Amphiura filiformis.*	b.	*Abra alba.*
Ch.	*Amphiura Chiajei.*	c.	*Macoma calcarea.*
S.	*Ophioglypha Sarsii.*	P.	*Pecten vitreus (abyssorum).*
Al.	*Amphilepis norvegica.*		

In addition to these 12 species, others might also have been included, as for instance *T.* — *Turritella terebra,* and *n.* — *Nucula sulcata* etc. which have previously been used in classifying communities. This would have given a fuller terminology; I have, however, considered the above mentioned 12 species as sufficient for characterisation of most communities. I have gradually come to regard *Am-*

phiura filiformis as better suited to this purpose than *Turritella*, being of somewhat more frequent occurrence, and being more characteristic for the community; the practice of referring to reduced *T.* stations without *T.*, is thus avoided, giving place to designations such as *Fil.* or *E. Fil.* etc.

If these 12 species occurred together and abundantly in all possible combinations in the sea, it would obviously be impossible to use them for classification; it has been found, however, that such is not the case. Both in Norway and Sweden, the Skagerak and the Danish waters we find, nearest to land, on open coasts, *v.* or *E. v.*; then follows *E. Fil.*; then *E. Fil. B. Ch.*, forming the transition stage to pure *B. Ch.*; in the deep water of the Skagerak we then find *B. S.* and finally, at greatest depths, *Al. p.*; practically but 5 pure communities, with their intermediate stages at interjacent depths: *v.*, *E. Fil.*, *B. Ch.*, *B. S.*, *Al. P.*

In the more sheltered waters, I have found nearest to land *d.* communities, in all such localities as I have investigated. These communities may be followed by *v.* or *E. v.*; frequently however, these last-named animals are here outnumbered by *b.*, *Abra alba* or *c.*, *Macoma calcarea* (in the Danish Belts and the western Baltic also by the *Astarte*-species, *a.*).

In open water from the coast and out to the greatest valuated depths we find:

v. with or without *E* etc. = called *Venus* communities with or without *E.*
E. Fil with or without *T* etc. = called *Echinocardium, Filiformis* communities.
B. Ch. with or without *n.* etc. = called *Brissopsis, Chiajei* communities.
B. S., frequently with attendant species = called *Brissopsis, Sarsii* communities.
Al. P. etc. = called *Amphilepis, Pecten* communities.

In more closed waters from the coast outwards:

d. with more or fewer attendant species = called *Macoma baltica* communities.
b. with or without E. etc. = called *Abra alba* communities.
c. with or without E. etc. = called *Macoma calcarea* communities.

With these eight terms, much can be done in the way of indicating the communities, especially when it is borne in mind that transition stages between adjacent communities naturally occur, and may, if desired, be taken as distinct communities in themselves; it should, however, not be forgotten that these brief terms necessarily do not pretend to indicate all particulars regarding contents and characteristic species of the different communities, but only point to the most important.

These eight communities, with the exception of the two deepest, *B. S.* and *Al. P.*, which are not found in Denmark, agree with those drawn up by me for Denmark in Report XXI p. 5—6. Two other communities referred to in the same work p. 8—9, *viz;* 1) the Haploops community, with *Haploops tubicola, Pecten septemradiatus, Lima loscombii, Ophioglypha robusta* as characteristic species, and 2) the deeper *Venus* community with *Spatangus purpureus, Echinocardium flavescens, Abra prismatica, Psammobia færoensis*, etc. are, in our waters, only found locally and at some few places; only traces of them were found in the Christiania Fjord and the Skagerak. I have therefore preferred to disregard them altogether in the present work.

In the Appendix to Report XXI (*vide* Report XXII, 1914) I have utilised a series of communities defined in a somewhat different manner for the purpose

of investigating their distribution outside Denmark according to statements made in the literature, and thus based on dredging hauls, etc. 'I was here obliged to take the two *Venus* communities together under one head, and exclude the *E. Fil.* community; the *B. S.* community, which is now recognised for the first time, was not included there at all.

The chart accompanying the Appendix must therefore be supplemented by imagining the *E. Fil.* community as situated at the boundary between the yellow and pale blue tints, and the *B. S.* community between the pale blue and dark blue areas; their actual distribution, however, is not exactly known.

With regard to the figures shown in the station lists here given, it should be noted that all indicate the number and rough weight of animals per 1 m^2 of sea bottom; in most cases, however, only 5 samples were taken with a 0.1 m^2 bottom sampler at each station, giving thus only 0.5 m^2 investigated; this result has then been multiplied by 2.

At Nos. 10 and 12b however, in the Christiania Fjord, 1 m^2 was investigated; at the latter station with the 0.2 m^2 bottom sampler. In the lists for the Skagerak also, there were as a rule only taken 5 samples at each station with 0.1 m^2; at Nos. 1—5 however, 10 samples, and at No. 4 in the North Sea, 8 samples each of 0.1 m^2.

All the figures in the lists are, however, mutually comparable, indicating in every case the quantity of animals per 1 m^2 of bottom.

The Horten profile (p. 11) was taken in a more or less straight line from Station 36 (*vide* chart) to Station 37, from 217 to 10 metres depth, with as a rule only one sample from each place with the 0.1 m^2 bottom sampler. A glance at this profile will, however, reveal a series of communities, between 15—21 m with *Fil.* (and *Turritella*) as characteristic species, and even an *E.* being found at the deepest of these stations. The shallowest sample contains altogether so few animals that only its *Aporrhais* tends to indicate the *v.* community. Two small *Fil.* I have not regarded as reliable indications, as such small animals may have remained hanging in the sieves from one station to the other, and it is therefore necessary to be careful in drawing conclusions from such occurrences, which may as a matter of fact be mere adulterations. From 50—63 m we have the *B. Ch.* accompanied moreover, by *Nucula sulcata*, and even some few *Amphilepis*, *Al.*; it should be remembered, however, that this animal's true community in the deep water is here situated so close at hand that a kind of »infection« might easily take place and spread to a certain degree, especially when, as in the present case, the total quantity of animal life is but slight, and competition correspondingly insignificant. As to how far the sample at 85 m should be taken as indicating a *B. S.* community, with its single *Ophioglypha Sarsii* and the lack of *Amphiura*, I cannot say; it would, in such case, present an excellent agreement with the conditions as found in the deep water of the Skagerak.

From 95—217 m *P. Al.* predominate, with *Dentalium striolatum*. The *B.* specimens found were mostly young, but they go unusually deep down. *Axinus flexuosus* occurs in this and the foregoing community.

We thus find, in this preliminary sketch profile, where several species were for practical reasons disregarded on board, a distinct order of pro-

The Horten Profile,

constructed on board, between St. Nos. 36 and 37. 8th July 1914.

	Al. P.												*B. S.* ?	*B. Ch.*					*Fil. (E.)*			*v.* ?
Depth in metres	217	214	210	180	172	145	135	110	102	100	98	95	85	63	62	53	50	50	21	20	15	10
Temperature in the bottom	6,3°	6,2°		6,3°	6,2°	6,2°	6,4°	6,5°	6,8°	6,4°	6,4°	6,5°	6,6°	6,7°	6,6°	6,6°	6,8°	7,0°	8,9°	8,9°	10,4°	15,2°
No. of samples of 0,1 m²	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	5
Pecten vitreus	×	⊗	⊗	⊗	⊗	⊗	⊗	×	⊗	⊗	⊗	×										
Portlandia sp.	1	3	⊗	1																		
Axinus flexuosus	×	×	×	×	×	×	×	×	1	×		×				×	×	2				
Nucula sulcata														1	1	3	3	10				
» *tenuis*		1					×															
» *tumidula?*											×	×										
Venus gallina																					1	
Neæra sp.						×	1								1							
Cyprina islandica																						2
Abra nitida																						9
Turritella terebra																			⊗	⊗	4	
Aporrhais pes pelecani																						1
Dentalium striolatum	2							×			1		4									
» *sp.*						×																
Eumenia crassa																	1		1			
Brissopsis lyrifera		1		2	2		×	2	1	1	3	1	1		1	1	1	2				
Echinocardium cordatum																			1			
Amphiura Chiajei														1	6	3	10	8	6			
» *filiformis*																			50	50	50	2
Ophioglypha Sarsii													1									
Amphilepis norvegica	4	4	1		10	6		1	1	2				3	4	5		1				
Calocaris M'Andreæ										1												

× indicates several specimens.
⊗ » dead shells.
Brissopsis lyrifera all small, with the exception of 3 at 98 m.
The two *Cyprina* at 10 m were small.

gression from above downwards, beginning with a faint *v.* station and thence to *Fil. T. — B. Ch. — B. S, — Al. P.* The temperatures in the profile were taken in the soft bottom material brought up, and show, with their high values in shallow water, a certain resemblance to the distribution of the communities. Such measurements of temperature serve, in my opinion, to give a better idea as to the mean temperature of the locality than would be obtained from temperatures taken in the water mass itself, since these latter give only the actual temperature prevailing at the moment of observation. Care should be taken, however, not to attach undue weight to such bottom temperatures, as they may frequently be taken some few cm higher or lower in the bottom material, which will doubtless also have affected our results to a certain extent; we endeavoured however, in all cases to read the lowest temperature obtainable in the bottom material examined.

Passing now from this preliminary profile at Horten, a better idea as to the contents and vertical distribution of the communities will be obtained from Profiles I—III, where Profile I embraces the Stations from W. of the Skaw to the

deepest water in the Skagerak, at 670 m depth; Profile II all stations in or near the southern portion of the Christiania Fjord south of Drøbak, and Profile III all stations beyond Drøbak. For details, *vide* explanatory note to Chart, p. 28.

In Profile I, Skagerak, the usual Kattegat communities are found from the coast out to about 90 metres depth; the *d.* community was not directly noticed here, but is known to occur in quite low water, *e. g.* in the inflow of the Limfjord, the Thyboron Canal, and on the coasts of Norway; true, it is not found on the very open coasts, where the action of the waves is too strong; young *Mytilus edulis* may, however, occasionally be found here. The other Kattegat communities extend deeper down in the Skagerak than in the Kattegat; the *B. S.* community will presumably occur just below 100 m depth. At 270 to 670 m we have the *Al. P.* community; these two deep communities are not found in the Kattegat. *P. vitreus* has only been found as empty shells in the bottom sampler in the Skagerak, but is known to live there (*vide* previous trawlings in Report IX). The empty shells doubtless originated from individuals recently deceased, devoured by predatory echinoderms. It should in my opinion be regarded as more or less of an »accident« that we failed to find *P. vitreus* in a living state at any of the few stations made with the bottom sampler in the Skagerak; it should be remembered, however, that the number of animals at the *Al. P.* stations in the Skagerak is altogether but slight.

Profile II, south of Drøbak, shows all the same communities as in the Skagerak, if St. 45 is to be regarded as typical of a *B. S.* community, or at any rate influenced thereby. All the communities — *d.* for obvious reasons excepted — are here found in shallower water than in the Skagerak; this is not, however, distinctly shown in the profile for the *E. v.* stations. Temperatures about 10° are encountered in the Skagerak down to 90 m, in the Christiania Fjord not deeper than 10—15 m.

Profile III, of the stations north of Drøbak, shows, at 0.3 m, a distinct occurrence of *d.*, then *d. b.*, at 6 m. Station 15 + 16 at 7 m in Christiania Harbour at Skarpsno exhibits quantities of *Mytilus*, as also *Cyprina*, with an entire absence of echinoderms; it forms a transition stage from the *d. b.* to the subsequent *b. c.* stations at 10 and 12 m with *Corbula gibba* as an attendant species. These two stations (Nos. 18 and 27) with their small *Cyprina islandica* and *Aporrhais*, remind one of the reduced *Venus* stations with *b.* and *c.* such as are found in several sheltered waters of the Belt Sea. No. 21, at 24 m, with its *Fil.*, resembles the poor *E. Fil.* of the Belt Sea, and has also *b.* and *c.*, with *Nucula nitida* and *Abra nitida* as attendant species. No. 29, at 29 m, has *B.* with *c.* and various attendant species; deeper still, however, at No. 28 (54 m) we find *E. c.*, *i. e. E.* deeper than *B.* This I have never seen in any other water; the order in which the animals generally occur in open water here appears to be partly dissolved, which fact agrees with the circumstance that the usual characteristic species for open water are here remarkably few and rare; echinoderms, for instance, are seldom found, the only species of frequent occurrence being the attendant *Axinus, Abra* and *Nucula*, with the species *c.* — *Macoma calcarea*, which is most characteristic for these stations. At 3 of the stations, *c.* amounts to over 60 individuals per 1 m^2, and forms here a dominant proportion of the total animal weight; it is

lacking only at Station 22. All stations beyond Drøbak from 24—73 metres depth must thus be characterised as *c*-stations with various attendant species; the stations from 12—7 m as *b. c.* stations, those at 6 m as *d. b.* stations, while at 0.3 m we have a pure *d.* station.

Only the two deepest stations now remain to be mentioned; these are No. 14, at 98 m, with a poor animal content of in all 11.8 gr and No. 17, at 250 m, in the Bundefjord, with a total animal content of about 0.1 gr annelids. At this last, nothing in the shape of a »community« can properly be said to exist; the place being practically a desert; competition among the organisms is here evidently greatly reduced, if not altogether absent, the only inhabitants being such few animals as are able, despite the unfavourable conditions, to maintain a bare existence.

At No. 14, however, the animals were numerous, though small; *Axinus* and 2 *P.* indicate that this must be regarded as a poor *P. Al.* community, such as are found at similar depths farther out in the fjord. *Al.* is lacking, it is true, in the samples at St. 14, but was however, found at St. 29 (29 m) on this profile, so that its absence in the samples from St. 14 must doubtless be merely due to paucity of occurrence on the whole: trawling experiments have shown that the usual deep water fauna, including *Al.*, is also to be found out here.

We have thus, in the Christiania Fjord, moved from *d.* via *d. b.* and *b. c.* to *P. Al.*, as we do in the more sheltered portions of the Belt Sea, the only difference being that the latter waters exhibit nothing corresponding to the deep *P. Al.* communities *).

With regard to the vertical distribution of the communities in the various waters investigated, an idea of this will best be obtained by comparing all the different profiles which have been constructed on the basis of the material just mentioned, with the exception of that for the northern part of the Kattegat, which has been taken from Report XXI, p. 5. The profiles may be seen compared at the end of the present work.

It is immediately apparent that the deep *Al. P.* community in the Skagerak only extends as far as 265 m, whereas in the Christiania Fjord, it is found as far up as 100 m depth. The wide range of depth in the Skagerak is however, only faintly indicated by the tabular arrangements here given, owing to the restricted size of the page. *Al. P.* here extends from about 265 m to about 700 m, thus covering large areas of the bottom in the Skagerak; probably between

*) Station 30, at 41—45 m light clay bottom, a little S. of Drøbak (*vide* list of stations, p. 23) and situated as close in to the steep rocky coast on the western side of the sound as we dared place the vessel, exhibited a content of such a nature that I have not been able to include it in any of the profiles. This is the only technically successful station where such exceptional conditions were found. The dominant animals in point of weight were 3 *Astarte sulcata* and 24 *Dentalium entalis*, while of frequently occurring species there were 18 *Amphiura filiformis*, and 24 *Ditrupa*. It should thus, despite its depth, perhaps be reckoned as a *Fil.* station; it included, however, also traces of *Brissopsis, Ophioglypha Sarsii, Amphilepis, Arca, Portlandia* etc.; *i. e.* of deeper species both *B. S.* and *Al.* — I have therefore omitted this station from the profiles, as it is altogether an exception to the usual order. I am unable to say, from this isolated phenomenon, whether such steep slopes in narrow sounds frequently exhibit such mixed communities or whether a greater number of samples may here be required in order to classify.

one-half and one-third. In all probability it occupies a similarly large portion of the bottom in the Christiania Fjord.

The *B. S.* community, which is known in the Skagerak from about 150 to about 190 m, covers no inconsiderable area here; up to the present, it is only certainly known from the Skagerak, but may, however, possibly be found at a single place in the Horten profile and in Profile II, S. of Drøbak.

Following upon this community, in the Skagerak, we have the *B. Ch.* community, which in the outer portions of the Christiania Fjord follows directly upon the *Al. P.* with the exception already referred to at Horten. In the northern part of the Kattegat it covers the deepest areas of the bottom. The uppermost limit for the pure *B. Ch.* community lies, in the Skagerak, at about 80 m, whereas in the Christiania Fjord it is about 30 m, thus exhibiting a similar upward movement to that noted in ths case of the *Al. P.* community. The northern part of the Kattegat occupies here an intermediate position, with limit at about 45 m.

The pure *E. Fil.* community is found in the Skagerak from about 40 m, in the Christiania Fjord, however, from 20—25 m only, and in the northern part of the Kattegat from about 12—20 m; *i. e.* a change of position parallel to that already mentioned. It reaches a remarkably high level in the northern part of the Kattegat, where sheltered by the north of Jutland.

v-communities with or without *E.* are found in the Skagerak down to 20—25 m, but in the Christiania Fjord, even on open coasts, only down to about 14 m, and in the northern part of the Kattegat to about 10 m.

The *B. Ch.* community doubtless covers, in all three waters, considerable areas of bottom; the *E. Fil.* and *v.*-communities on the other hand form only narrow belts in the Christiania Fjord so near land as to be difficult of access for a vessel; the *d.* communities must here almost invariably be investigated from a boat, owing to the very slight depth at which they occur.

In the comparative table of the 5 profiles, several waters have been marked with a (*d*); this indicates that the community in question was not found in the present investigations, but that it may doubtless be found near land in suitable localities, at any rate in the harbours. Where no harbours at present exist, it will make its appearance as soon as such are built.

In the Christiania Fjord N. of Drøbak, *i. e.* in highly enclosed fjords, the deeper parts of the bottom, up to 100 m, are covered with *Al. P.* communities; then follow *c.* communities, influenced as regards their upper portions by *b.*, while higher again we find *b. d.*, and finally, close in to land, the pure *d.* communities.

The method here introduced, of indicating the different communities by means of short terms formed by abbreviation of the Latin names, renders it possible to characterise the nature of the various waters as regards their fauna with a simplicity unattainable when working with long lists of species. By adopting this system of terms for characterisation of the different larger fjords and other waters in Scandinavia, especially in Norway, a comprehensive view of the subject might be arrived at, such as is now entirely wanting.

The Gullmarfjord, for instance, is in the main characterised by the communities *d., v., Fil., B. CH,* while the Koljefjord, in the vicinity, is like many other fjords, a *d. c.* water. The Christiania Fjord below Drøbak may

be termed *d., E. v., E. Fil., B. Ch., Al. P.;* while above Drøbak it is a *d., c., Al. P.* water. With such a system of terms it is possible to obtain a clear idea of the conditions, and the water can then be charted accordingly; with lists of species, on the other hand, no such survey is possible.

Zoologists and geologists have long endeavoured to obviate these difficulties by selecting certain characteristic species from the long lists of species, the species thus chosen being such as were possessed of particularly reliable qualities, such as occurring exclusively in ice-cold water, in very deep water, in fairly warm water and the like. Much has been gained by this method; beyond this, however, nothing at all has been done in the way of describing the fauna as a whole. The lists in their complete state are too long, the few selected species not sufficiently numerous, save where they happen to be of high quantitative importance at the same time; as to this, moreover, little or nothing is known. Only the true characteristic species of the communities can properly be taken as basis for a description of the fauna of the sea bottom.

As to the precise value of the communities themselves from a descriptive point of view, this can hardly be determined without due investigation; the reader may here refer to the Appendix to Report XXI, published in Report XXII for 1914, and to the chart there given of the probable distribution of the communities outside Denmark.

In especially selecting the conchiferous molluscs and the echinoderms for characterisation of the communities, I have done so with a purpose, these two groups composing, as a rule, by far the greatest part of the bottom fauna, in addition to which, they are not seasonal animals; *i. e.* they do not generally die off at certain seasons of the year. They are comparatively easy to determine, which fact is of great importance when dealing, as here, with different groups of animals, some of which will necessarily be less familiar to the investigator than others. The chætopods, which are also quantitatively important, are difficult to determine as to species, at any rate by hurried inspection on board, and I have therefore omitted them from these lists, although several of the species seem excellently suited for characterisation of communities. The remaining groups need not here be dealt with in detail, being but scantily represented, from a quantitative point of view, in the lists.

The conchiferous molluscs and the echinoderms can, moreover, on account of their high calcareous content, be dried, without rendering identification impossible or impairing the habitus, and may therefore, when preserved in boxes, serve to give a picture of the respective communities which can be taken in at a glance, thus facilitating the work both for ourselves and others desirous of studying the communities.

It need hardly be said that communities noted in the same terms on the profiles will be found to be analogous throghout when compared one with another; as regards the degree of analogy existing between the different waters, this is immediately apparent from the profiles themselves. Thus the Christiania Fjord S. of Drøbak is analogous with the Skagerak; the *B. S.* community is particularly referred to on p. 14. The whole of the Christiania Fjord is analogous with the

Skagerak plus the Danish waters as far as Bornholm, both terminating, as regards their inner limits, with *d. b.* and *c.* stations, etc.

Apart from the bottom sampler, there is, as already mentioned, but one method of making comparison between the fauna of one water and another, *e. g.* the Christiania Fjord and the Kattegat, *viz.* by comparing lists of species, as complete as possible, for the different groups, molluscs, annelids, echinoderms, etc. With the bottom sampler, however, other methods may be employed; thus one can, for instance, analogise the different communities in both waters, and thus obtain a far better idea as to the distribution of the fauna in the waters in question. It is moreover far easier to determine a community from the species of common occurrence therein than to procure complete lists of species. In such lists, a rare species, of which perhaps but a single specimen has been found, will appear of equal importance with a common species, found represented in every 1 m^2 throughout large areas of bottom. Finally, it is also possible to compare the species found in analogous communities from both waters, both as regards the common species and those of rare occurrence.

Attempts have frequently been made in zoogeography to define certain regions for the distribution of the various kinds of fauna by means of given external conditions, such as depth and temperature; a comparison of the profiles will, however, show how variable are the depths which form the limits of occurrence for the same community in closely adjacent waters, The temperature again, is not much, though possibly a little, better; it will be noticed that there is but slight difference, if any, between the haunts of the *Al. P.*, *B. S.*, and *B. Ch.* communities, while in shallower water, we find the temperature varying greatly according to time of year.

The temperatures here given, however, in the comparison of the 5 profiles, are in all cases midsummer figures, and furnish thus a very fair idea of the conditions; we find, for instance, 10.0° at 90 m in the Skagerak, whereas in the Christiania Fjord, this temperature is not reached below about 15 m. I have not the slightest doubt that this feature stands in some relation to the upward movement of the communities in the Christiania Fjord towards shallower water; as already mentioned, however, these temperatures change with the changing seasons, whereas the communities themselves remain constant, as regards their characteristic species; these last should therefore alone be taken as foundation for zoogeographical description. Depth *qua* depth exerts but slight influence upon the occurrence of communities; temperature evidently more; there are doubtless many other factors, however, which likewise play some part, though we do not at present know them all.

Those water layers of the Christiania Fjord which are warm in summer are evidently but of slight thickness in comparison with those of the Skagerak and northern part of the Kattegat (*vide* Hjort and Dahl: Fiskeforsøg i Norske Fjorde, 1899); had the depth profile of the first named water however, been different, *e. g.* flatter and more sandy, it might have afforded good grounds for rich communities of *d.*, *v.*, and *E. Fil.*, which have now to be painfully sought in certain shallow creeks and fjords.

The sudden appearance of *Macoma calcarea* north of Drøbak in quantities similar to those encountered in the Danish Belt Sea, together with the partial dissolution and impoverishment, both as to number of species and number of individuals, of the usual communities in both places, is not to be explained either by temperature or other known physical conditions. As regards our waters, it has been suggested that the inferior salinity of the water nearer the Baltic might account for the rich developement of this »arctic« form here; the other arctic form, *Astarte borealis*, which is entirely lacking in the Christiania Fjord, is also found in our waters. I have myself for a long time inclined towards the same opinion; in the Christiania Fjord, however, where there is no very great difference either in temperature or salinity between the water north and south of Drøbak, this explanation cannot be regarded as correct. The difference between the fauna of the two localities is also distinctly apparent in other respects, as for instance from the comparatively rich developement south of Drøbak and the partial dissolution of the communities north of same, up to Bundefjord, where the fauna is almost nil.

Hjort has (l. c.) called attention to the slight degree of circulation, and paucity of oxygen, etc, in the water of the closed fjords; even this, however, does not explain why *Macoma calcarea* should exhibit particularly rich developement here rather than elsewhere; if it can live here, then one might well suppose that it could live anywhere. I may in this connection refer to my remarks in Report XXI, p. 29 ff. but would here briefly mention that we have doubtless in this case to reckon with the question of competition between different species, where chemico-physical explanations alone will not suffice. In my opinion, it is highly likely that the struggle of species against species may be a far more important factor in the formation of communities than is generally supposed; the destruction or exclusion of certain forms on a given ground, instead of being occasioned by the slight differences in external conditions, might well be rather due to competition on the part of other species better adapted to such conditions as there prevail. — In this connection also I recall a circumstance noted years ago on the cruises of the »Hauch«; that closely related species, especially those of the same genus, are scarcely ever found living in one and the same area of a given water; they may meet, and fight out their war on a frontier line, but are never found to cover the same area of distribution altogether. Each has its own region, its own community. The competition must be greatest between those species which are most closely related.

True, it is often easy to point out a certain parallelism between distribution and external conditions; great caution should, however, be exercised in regarding external conditions as directly responsible for the presence or absence of any species.

As mentioned above, certain small species such as especially *Axinus flexuosus, Nucula tenuis, Abra nitida,* etc., may occur as attendant species at greatly varying depths. *A. nitida* extends from the Limfjord at 4—6 metres to 300—400 m in the Skagerak, being most common at about 200 m, with over 700 specimens per 1 m². *A. flexuosus* is found from the Sound S. of Hveen at about 20 m down to over 400 m in the Skagerak, and is very numerous here; the same applies to *N. tenuis;* only in the true *d.* community is it wanting. They may

thus be found in almost all communities. Among the annelids, a similar distribution is known in the case of *Terebellides Strømii*, and possibly several other species.

In the Limfjord, however, only young specimens of *A. nitida* are found, the older ones keeping apparently to deeper water in the Skagerak or Kattegat and similar waters; the species would seem to be excluded from sandy bottom, preferring softer ground. In the *B. S.* community in the Skagerak especially it is common, with over 700 per 1 m². The two other bivalves are likewise found most frequently in deeper water in the Skagerak than elsewhere, as also north of Drøbak, and I have never found such large shells of *A. flexuosus* as in the Bundefjord and the almost barren fjords near Kristineberg; it would seem as if they at times found particularly favourable conditions here. At the *B. Ch.* stations in Kattegat, all three are as a rule very scantily represented. I could imagine that these species might as a matter of fact only be really at home in deep water (*B. S.* etc.) and that those found in shallower water had been brought there by a kind of »infection« from the deeper parts; in other words, that if they were exterminated in the deep water, they would soon disappear from the shallower regions adjacent.

This suggestion I leave to be further tested, merely adding, that these attendant species show how it is possible for certain species to live under widely differing external conditions, at any rate for a time; that they are lacking in some localities may perhaps be due to their having been exterminated there by competition with other species.

Of the animals taken with the bottom sampler on this cruise, about 15—20 litres consisted of forms also commonly found in Danish waters, only a handful belonging to species not found from the Skaw inwards. Among these last named may be mentioned two characteristic species: *Amphilepis norvegica* and *Pecten vitreus*, and in addition, *Abra longicallis*, *Portlandia lucida* and *P. tenuis*, *Nucula tumidula*, *Axinus croulinensis* and *A. ferruginosus*, several species of *Neæra*, *Arca pectunculoides*, *Siphonentalis tetragona*, *Dentalium striolatum*, *Munida rugosa*, *Eiconaxius cironatus*, a pennatulid, *Kophobelemnon*, certain *Spongiæ*, *Echinocucumis typica* etc. We have thus a lengthy list of species, which could be further increased by renewed investigations, but having an extremely poor animal content as a whole. These species, being deep water forms, are naturally lacking in the Kattegat, and the deep water being apparently poor in animal content throughout, the total weight of individuals of these species is naturally but small.

The paucity of the fauna in the water north of Drøbak is not, in my opinion, any proof in itself of a general diminution in the quantity of animal life with increasing depth, being rather due to purely local conditions; the proof is found, however, in the poorness of the fauna in the deepest parts of the Skagerak and the southern portion of the Christiania Fjord. Disregarding the annelids, we find in the deepest *Al. P.* stations only about 10—20 gr animals per 1 m² in both waters; with the appearance of *Brissopsis* farther up, and higher again *Amphiura*, the animal content exhibits a distinct increase, amounting in the Skagerak to over 1000 gr per 1 m² at a single station, and in the southern part of the Christiania Fjord to over 400 gr.

As regards the *v.* and *d.* communities in shallower water, I will merely mention that their animal content is highly variable, and at Station 15—16 near Skarpsno (7 metres) amounts to over 2000 gr per 1 m².

In face of the fact that during the whole of this cruise the total quantity of animals taken amounted to but 15—20 litres, representing an area actually investigated of some 40 m² only — this being the total extent of ground covered by all the samples together — it might well seem preposterous, at least to those unacquainted with the work, to suggest that this should suffice for a general characterisation of the main features of the animal communities on the level bottom of the waters in question. A research vessel at work has been compared to a balloon with a man in, sailing over a landscape concealed by fog, and towing an apparatus with which to drag up samples from the earth, these being examined from time to time. This comparison was true enough as regards the earlier dredging investigations, where it generally sufficed to examine the animals which might be caught, without any regard to what might be the actual state of the bottom fauna as a whole. In these waters, however, the level bottom is to be imagined as consisting of almost level plains of soft clay, peopled with a fauna as uniform in character as the heather on a moor or the grass in a meadow. A few samples taken with the bottom sampler — or even a single one — would suffice to indicate heather, another elsewhere grass, and the main features of the »community« would thus have been determined. The fauna of these clay plains below the sea is far more regular and uniform than the fauna on land. I do not know if any great results can be attained at all by means of such quantitative investigations of the land fauna. The well known work of *P. E. Müller*, however, upon woodland earths, exhibits considerable similarity to these, and in the case of the plants, we have the classic investigations made by *Eug. Warming* and *Raunkiær*.

I must admit, however, as regards my own present investigations, that these give but an idea of the very commonest animals of the communities, species which are in any degree rare are as rule not taken at all, and the same applies to all those swiftly moving animals which hover above the bottom. Of fish, for intance, the only one taken was a single hag *(Myxine glutinosa)*. Once the extent of a community has been more or less accurately charted, however, it will be easy to add these other forms by fishing the ground in question with apparatus suited to the purpose. I need not go further into this part of the question here, but may mention that I have, on this cruise, also employed trawling implements, both north and south of Drøbak, and have also, on a previous occasion, investigated the deeper parts of the Skagerak by this means *(vide* Report IX, 1899). We may therefore say that in addition to the common small forms brought up by the bottom sampler, as for instance, from the *Al. P.* community, there will also be a great number of other rarer animals per 1 m² N. of Drøbak, such as *Stichopus tremula, Pandalus borealis, Gadiculus Thori, Lycodes sp., Pleuronectes cynoglossus* etc., while south of Drøbak, were found 35 specimens of *Munida rugosa*, besides *Astropecten Andromeda, Mesothuria intestinalis, Stichopus tremula*, 1¼ Litres *Pandalus borealis, Lycodes Sarsii, Lycodes Wahlii, Motella sp., Gadiculus* etc. — a fauna strongly resembling that of the deeper parts of the Skagerak. These animals are however, doubtless not entirely restricted to the *Al. P.* community; some of

them, as for instance the large holothurians, are also found in other communities in shallower water. The correct distribution of these animals among the different communities must be left to future investigations. I may here call to mind that Appelløf's description (Murray and Hjort: The Depths of the Ocean, p. 482) of the deep-water fauna in the Norwegian fjords, and later in the same work (p. 503—4) of that of the Skagerak, exhibits a remarkable similarity to the contents of the *Al. P.* stations as here shown. I am thus by no means inclined to suggest that investigations should be restricted to work with the bottom sampler; this should merely form the skeleton upon which the whole is built. The bottom sampler has, moreover the advantage of furnishing a rapid survey, which is obtained, not by examination of large areas, but by means of a number of small, correct pictures of the uniform communities of the level bottom.

The fauna both of the Danish waters and of the Christiania Fjord has now been subjected to investigation for some score years; as far as I am aware however, no actual comparison between the two has hitherto been made. It would indeed have been difficult to do so with the old method of investigation, based as it was upon dredging, and with separate treatment of each group of animals, which furnished no comprehensive view, but merely a series of long lists for the different groups. We know now, however, that it is only by investigation of the communities themselves that it is possible to arrive at a true comparison which furnishes a proper idea of the respective conditions. One might easily imagine two waters exhibiting approximately the same list of species, but yet differing in a very high degree; the frequency with which individuals of the various species occur forms a factor which cannot be disregarded. An ornithologist, for instance, might easily in the course of many years collect such a number of rare birds in Denmark as would, when recorded without comment, furnish a list of species giving an entirely erroneous idea of the feathered fauna of the country.

One point to which I wish to call attention here is the great paucity of fish in the deeper waters both of the Skagerak and the Christiania Fjord. Trawlers avoid the deeper parts of the Skagerak, as it does not pay to fish there, and our fishermen never go farther than the *B. S.* community at the outside, this being the extreme limit of occurrence of the *Pleuronectes cynoglossus* (the pole-dab) in any quantity. Plaice are not found here, keeping to *E. V.*, *E. Fil.*, and possibly part of the *B. Ch.* communities, while the haddock is hardly found beyond the *B. S.* community.

The poor bottom fauna in the deep parts north of Drøbak agrees well with the slight quantity of bottom fish found there, and it immediately occurred to me that the fishing industry in these waters could not be based to any essential degree on fish, the deep sea shrimps *(Pandalus)* being a far more likely object; both we ourselves and the shrimp trawlers working there took far more of these than of fish in the hauls observed.

According to the Norwegian statistics, about 155,000 litres of *Pandalus borealis* were taken north of Drøbak in 1913, representing a value of about 60,000 Kr. The yield of deep-water fish such as ling, haddock, halibut amounted to about 3—4000 Kr.; then comes, under the heading of »Flyndre« and cod together, a yield of about 57,000; not all »Flyndre« however, are pole dab, and most of the

cod are doubtless caught in shallower water; I have therefore no doubt that by far the greatest part of the yield in deep water consists of *Pandalus*. This fjord is, as regards its deeper parts, a shrimp fjord, not a fish fjord. The shrimps live partly on detritus of the bottom, and partly on smaller crustaceans, themselves doubtless also detritus eaters. The quantity of plankton on the bottom in this deep fjord is doubtless very slight.

In the *d*-community were also taken eels to the value of 15,000 Kr.; the eel is here, as in our waters, confined to this community during the earlier period of its growth. Herring, mackerel and garfish were taken in 1913 to the value of over 200,000 Kr.; these are migratory fish, and would probably for the most part have been spawned elsewhere; in any case, they have nothing to do with the bottom in deep water. —

In the course of this cruise it was found that the bottom sampler may be used without difficulty down to depths of at least 700 m.; that the communities known from the Danish waters were also to be found here, and that the two deeper communities lacking in our waters could be characterised; and further, that the investigations in question throw a new light upon questions both of earlier and recent date. It is to be hoped that these investigations may be continued in Norway, so as to furnish information regarding all the communities right up to the arctic regions. The profile method will doubtless here be preferable to charting of the waters on these very broken coasts, where it is almost impossible to draw an isobath at all.

As regards one side of the communities, the epi-communities, on the hard bottom, very little is known; how far this part of the question can be investigated with the bottom sampler I cannot say. It is possible that it may prove more successful than the dredge, though it may leave something to be desired in quantitative respects. Even at the few unsuccessful stations we encountered, the bottom sampler brought up something, thus for instance at No. 6 (70 metres), we found both *Crania anomala*, *Terebratulina* and *Mytilus phaseolinus*.

It is possible that *Mytilus edulis*, *Mytilus modiolus* and *Mytilus phaseolinus* form a succession of descending steps towards the deep water in the epifauna communities. I am inclined to believe that for each community on the level bottom there exists one or more corresponding epifauna. In the *d.* communities we know of an epifauna attached to stones consisting of *Balani*, *Littorina*, *Patella*, *Mytilus edulis* etc., and another among the *Zostera*, such as *Rissoa membranacea*, *Rissoa inconspicua*, *Mytilus edulis* etc., and possibly others; in the same way, we have an epifauna with *Mytilus modiolus*, *Ophiopholis aculeata* and other echinoderms on the *E. Fil.* community. Possibly it may also occur on other communities, such as *E, v.;* here also, however, there will doubtless be found other epi-communities on stones and algæ in shallower water. On the deeper community *B. Ch.* there are traces of a new epifauna with *Crania anomala* and *Mytilus phaseolinus*, and if I am not mistaken, Appelløf (l. c., p. 483—6) is of opinion that the *Al. P.* community has its corresponding epifauna with *Paragorgia*, *Lophohelia*, *Terebratulina* and *Gorgonocephalus Linckii* in the Norwegian fjords, and that similar epi-communities likewise occur outside the fjords. All this needs, as already mentioned, to be further investigated.

In this connection I may mention that a fisherman from the Skaw presented me this year with a splendid specimen of *Gorgonocephalus Linckii*, taken, as he informed me, on hard bottom at about 200 m depth N. of the Skaw; there must thus also be an epifauna here.

If it be asked whether we may suppose that the production of animal matter on the sea bottom in the deep waters here investigated really is so slight as indicated by the small quantities of animals per 1 m^2, I must first of all point out that the rough weight of the animals, with the highly variable quantities of water and calcareous substances, gives but a poor expression of the true organic matter. Even apart from this, however, and taking the quantity of water and calcareous matter in the animals as more or less identical for deep and shallower water, care must always be exercised in drawing conclusions from the magnitude of animal content at any given time to that of the annual production, this latter being in a very high degree dependent upon longevity and rate of growth. With regard to these two factors, practically nothing is known in the case of the deep-water animals; I should not be surprised however, if it were found that the production in deep water were even far slighter than the low animal content itself appears to indicate.

Finally, I beg to thank Cand. mag. Ad. S. Jensen, for his help in determining the rarer species of deep-water molluscs, and Cand. mag. K. Stephensen for similar assistance with the crustaceans; altogether, I may say that we should be very often at a loss in these investigations if it were not for the staff of the University zoological Museum and the collections there preserved. I further desire to express my thanks to Professor Dr. H. Théel and Dr. phil. H. Østergreen, of the Kristineberg Zoological station, for their kindness during my stay there, and to the Director of Fisheries for Norway, Dr. Johan Hjort, who accompanied me throughout the whole of the cruise in Norway, and helped us over all the difficulties attendant upon investigations carried out in foreign territorial waters; last, not least, to Hr. Udsendt Vicekonsul and Chancelier Ove Lunn, in Christiania, and Hr. Vicekonsul Christensen in Sandefjord, to both of whom I am indebted for valuable information and other assistance.

List of Stations, with position, etc.

Stations in the Skagerak 1911—12 and 1914.

No.	Date.	Locality.	Depth in metres	Bottom temp.	Nature of Bottom.
1.	$^{8}/_{7}$ 1911	2 nml. N. of Skaw Lightship.	90	10,0°	Highly compact sand with finer particles here and there. A very distinct brown upper layer. Blue-black particles lower down.
2.	$^{8}/_{7}$ 1911	13 nml. N. N. O of Skaw Lightship.	160-173	7,0°	Kattegat clay with brown upper layer; very dark in the lower layers.
3.	$^{3}/_{9}$ 1912	4,5 nml. E.$^{1}/_{2}$ N. of the Skaw.	53		Kattegat clay.
4.	$^{15}/_{5}$ 1914	16 nml. N. E. by N. $^{1}/_{4}$ N. of the Skaw Light.	186-187	6,5°	Kattegat clay.
5.	$^{16}/_{5}$ 1914	32 nml. N. N. W. of the Skaw Light.	410-430	6,3°	Light, soft Kattegat clay with some few *Zostera* leaves.
6.	$^{12}/_{7}$ 1914	Abt. 25 nml. S. E. of Risør.	635-670	6,2°	Light, soft Kattegat clay in sample No. 4 (the deepest) also small stones.
7.	$^{12}/_{7}$ 1914	23 nml. N. of Skaw Light.	150	7,2°	Grey clay with brown upper layer.
8.	$^{13}/_{7}$ 1914	Off Spirbakkens Baake.	15		Coarse sand, gravel and small stones. Many dead shells, expecially of *Mactra subtruncata.*
9.	$^{13}/_{7}$ 1914	Off Spirbakkens Baake.	23		Dark sand with detritus. Many dead shells, including those of oysters, *Modiola* and *Macoma calcarea*, but also of *Venus gallina, Tellina fabula* and *Dosinia.*
10.	$^{13}/_{7}$ 1914	Abt. 3 nml. N. of Spirbakkens Baake.	41		Dark clay, very sandy.
11.	$^{13}/_{7}$ 1914	Abt. 4 nml. N. of Spirbakkens Baake.	68		Dark clay with some sand. Dead shells of *Solen ensis* and *Psammobia fœroensis.*
12.	$^{13}/_{7}$ 1914	Abt. 5 nml. N. of Spirbakkens Baake.	91		Lighter clay, with som e sand.

In the Skagerak are also included: North Sea No. 4

4.	$^{13}/_{7}$ 1911	60 nml. N. by W.$^{1}/_{4}$ W. of Thyboron Channel. Falls outside the chart. (*vide* Report XXI p. 38.)	275-280	6,5°	Light clay with no distinct brown layer (brown layer possibly washed away?) Bottom sampler reached about 8 cm. down in the bottom.

and Christianiafjord No. 8.

8.	$^{3}/_{7}$ 1914	Abt. 2,5 nml. N. W. of Thorbjørnskær Light.	350 410	6,8°	Light, bluish clay with thin brown layer.

At Stations Skagerak Nos. 1, 2, 3, 4 and 5 ten samples of 0,1 m² were taken.
North Sea No. 4 eight samples at 0,1 m². All other stations five samples of 0,1 m².

Stations in the Christiania Fjord 1914. S. of Drøbak.

No.	Date.	Locality.	Depth in metres	Bottom temp.	Nature of Bottom.
1.	3/7	Abt. 0,3 nml. S.S.W. of Channel Light, Moss.	14	8,5°	Dark clay.
2.	3/7	Between Moss and Rævlingen.	29	6,5°	Grey clay.
3.	3/7	S.W. of Moss, abt. 0,7 nml. N.W. of Rævlingen.	74	6,2°	Light, tough clay and small stones.
4.	3/7	Abt. 1,4 nml. S. of Rødaas (Jæløen), 1 nml. W. of Rævlingen.	138-150	6,2°	Light clay with a thin brown layer.
5.	3/7	Abt. 2,5 nml. S. of Gulholmen Light, 1,7 nml. E. of Bastø-Kalv.	280	6,1°	Light, tough clay with distinct brown layer.
6.	3/7	Rier-Grounds, W. of Struten Light.	70-75	6,7°	Light, grey clay with stones and *Crania anomala* (rock?) Valuation impossible.
7.	3/7	Abt. 3,5 nml. N. N. W. of Thorbjørnskær Light.	50-85		Clay with small stones (rock?) Valuation impossible.
8.		Included under Skagerak.			
9.	3/7	Anchorage in Sandøsund, E. of Vasser.	13		Sand with small stones and slag.
10.	4/7	Abt. 2 nml. E. of Busteen Island.	70	7,2°	Soft, light clay.
11.	4/7	Abt. 1 nml. E. of Fulehuk Light.	98		Light clay.
12a.	4/7	W. of Svarteskärsrinnen, abt. 1 nml. N. of Rauø Kalv.	17		Sand, stones and clay with dead shells and red algæ.
12b.	4/7	W. of Svarteskärsrinnen, abt. 1 nml. N. of Rauø Kalv.	14		Large and small stones, some clay and sand.
13.	4/7	Drøbaksund, off Hvidtsten.	200	6,2°	Grey clay with small stones and brown upper layer.
30.	8/7	Drøbaksund, off Teien S.	41-45	6,2°	Light clay. Contents mixed.
31.	8/7	W. of Jæløen N., abt. 0,7 nml. S.S.W. of Bævø.	28	6,5°	Light clay.
32.	8/7	W. of Jæløen, abt. 0,5 nml. N.W. of Næskrakken.	46	5,8°	Light clay and small stones.
33.	8/7	W. of Jæløen, abt. 0,4 nml. N. N. E. of Rambergnebba.	4		Dark sand with green *Zostera*.
34.	8/7	W. of Jæløen, abt. 0,4 nml. N. of Rambergnebba.	10		Dark sand with detritus.
35.	8/7	W. of Jæløen, c. 1,5 nml. N. of Gulholmen Light.	41	8,0°	Light clay.
36.	8/7	Abt. 1,5 nml. S.W. by S. of Gulholmen Light.	145	6,2°	Light clay with some stones and slag, brown upper layer. Horten profile begins here.

No.	Date.	Locality.	Depth in metres	Bottom temp.	Nature of bottom.
37.	$^{8}/_{7}$	Close to coast N. of Aasgaardsstrand, 1 nml. W. N.W. of Bastø Kalv.	10	15,2°	Dark sand with detritus.
38.	$^{9}/_{7}$	Off Tønsberg; midway between Vallø and Rauø Kalv.	320-328	6,5°	Light grey clay with brown upper layer.
39.	$^{9}/_{8}$	Off Tønsberg; between Rauø and Torgersø.	120	6,3°	Grey clay.
40.	$^{9}/_{7}$	E. of Bolærnene, abt. 1 nml. N. E. of Hesteboene.	65	6,5°	Light clay.
41.	$^{9}/_{7}$	E. of Bolærnene, abt. 0,2 nml. N.N.W. of Hesteboene.	21		Stones and shells.
42.	$^{9}/_{7}$	E. of Bolærnene, abt. 0,4 nml. N. of Hesteboene.	24-30	9,6°	Light clay.
43.	$^{9}/_{7}$	E. of Hvaløy, N. of Gaasø.	37	6,5°	Light slay.
44.	$^{10}/_{7}$	Anchorage in Vestergaardskilen near Vasser.	10	13,6°	Dark and sandy bottom.
45.	$^{10}/_{7}$	1,5 nml. S. W. by S. of Færder Light.	77	7,1°	Clay, with gravel and large and small stones.
46.	$^{10}/_{7}$	S. of Sandefjord, abt. 1 nml. N. of Rauøerne.	25		Coarse gravel and large and small stones, with *Delesseria*. Valuation impossible.
47.	$^{10}/_{7}$	Nevlunghavn; between the town and Hellholm.	24		Dark sand with some clay and detritus.
48.	$^{10}/_{7}$	Nevlunghavn, off Labjerg.	14		Dark, somewhat finer sand, with detritus.
49.	$^{10}/_{7}$	Sandefjord, between Haakevik and Ogaardsboe.	74	6,5°	Light, very soft clay.
50.	$^{11}/_{7}$	Sandefjord, anchorage near Buerø.	9	16,6°	Dark sand, a very little green *Zostera*.
51.	$^{11}/_{7}$	Base of Sandefjord.	8	16,8°	Dark, shaking mud in three samples, sand in two.
52.	$^{11}/_{7}$	Sandefjord, off Rydningen.	22	10,2°	Bottom covered with coal slag and stumps of wood. Valuation impossible.

No. 30. Mixed St. (5 samples of 0,1 m²). — No. 36. Included in Horten Profile.
No. 6, 7, 46, 52, Valuation impossible -- No. 12b. 5 samples of 0,2 m².
No. 10, 45 (10 samples of 0,1 m²). — No. 11 (2 samples of 0,1 m²).
All other stations each 5 samples of 0,1 m.

Stations i Christiania Fjord 1914. N. of Drøbak.

No.	Date.	Locality.	Depth in metres	Bottom temp.	Nature of Bottom.
14.	$^4/_7$	Between Steilene Light and Slemmestad factory.	98	7,0°	Grey clay.
15&16.	^{4} & $^6/_7$	Anchorage off Skarpsno.	7	18,0°	Bottom black, soft, fresh-smelling.
17.	$^6/_7$	Bundefjord, off Rudstrand.	150	6,5°	Dark clay with brown upper layer.
18.	$^7/_7$	Langaarsund, off N. E. end of Langaaren.	12	10,2°	Light clay.
19.	$^7/_7$	Langaarsund, off Vieren.	6		»Gytje« (shaking mud).
20.	$^7/_7$	Langaarsund, Bay E. of Vieren.	0,3		Soft blue clay without vegetation, many remains of *Zostera*.
21.	$^7/_7$	Langaarsund, between Møllereng Bay and Hareholm.	24	5,5°	Grey clay.
22.	$^7/_7$	Langaarsund, between Gaasøen S. and Hareholm.	39	6,1°	Light clay.
23.	$^7/_7$	Langaarsund, abt. 0,3 nml. S. S. W. of Gaasø.	73	6,7°	Clay, with fragments of wood and small stones.
24.	$^7/_7$	S. W. of Gaasungerne.	32		Rock with *Ascidiæ*. Valuation impossible.
25.	$^7/_7$	Lysaker Fjord, between Rolfstangen and Hulskær.	72	6,8°	Dark grey clay.
26.	$^7/_7$	Lysaker Fjord, between forest and Tornebu.	36		Dark grey clay.
27.	$^7/_7$	Lysaker Fjord, W. of Killingholm.	10		Clay and small stones.
28.	$^7/_7$	Abt. 1 nml. E. by S. of Nesodden Light.	54	7,3°	Grey clay.
29.	$^7/_7$	Abt. 0,3 nml. S S. W. of Nakholm.	29	6,4°	Grey clay.

5 samples of 0,1 m^2, taken at all stations except Nos. 15 and 16 and Nr. 17, where 10 samples 0,1 m^2 were taken. — At No. 24 valuation was impossible.

With regard to the profile in the northern part of the Kattegat, *vide* Table p. 5 in Report XXI and Chart No. 1 therein. It is composed of Stations 15, 14, 16, 19 and 20.

Explanation of Chart.

The round black points indicate the stations where samples were taken, or attempted, with the bottom sampler, *vide* full list of the separate stations *supra*. The letters placed near the points, and frequently joined with a line, indicate the animal communities of the stations, as *bc. Al. P.* etc.

The 5 profiles referred to in the text, and compared together in the diagram appended are:

The Skagerak Profile No. 1 a+b, formed by stations 1—12 from the vicinity of the Skaw and northward from there, with an older station No. 4 west of the margin of the chart, and Station 8 in the deep water near Færder.

The southern Christiania Fjord No. II a+b, formed by all the successful stations marked on the chart in and near the Christiania Fjord south of Drøbaksund, except No. 8 under Profile No. I.

The Northern Christiania Fjord Profile No. III, formed by all the successful stations marked on the chart north of Drøbak.

The Horten Profile is formed by a series of separate trial stations between No. 36 and No. 37 near Horten. *Vide* p. 11.

The Northern Kattegat Profile is that from Report XXI p. 5 and is formed by the five stations marked on the present chart as Nos. 14, 15, 16, 19, 20 from S. of the Skaw over towards Winga.

On Profiles I—III the names of the most important species are printed in italics.

Profile Ia. Skagerak.	*Al.* (*P.*)		*Al.* (*P.*)		*Al.* (*P.*)		*Al.* (*P.*)		*B. S.*		*B. S.*		*B. S.*	
Station No.	S. 6		S. 5		Kr. 8		V. 4		S. 4		S. 2		S. 7	
Depth in metres	635–670		410–430		350–410		275–280		186–187		160–173		150	
Temperature (Celsius)	6,2°		6,3°		6,8°		6,5°		6,5°		7,0°		7,2°	
No. & weight in gr. pr. 1 m²	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.
Abra nitida			2	0,1	40	3,6			716	70,0	377	60,0	348	39,0
» longicallis							1,3	0,75			1	0,1		
Neæra obesa					2	0,2			1	0,1			2	0,2
Cardium minimum							17,5	0,25	45	0,7			2	0,2
Axinus flexuosus			61	2,8	116	6,0	27,5	1,13	78	3,0	29	12,5	36	1,6
» croulinensis			21	0,2										
» ferruginosus			1	0,1										
Montacuta (?)					2	0,2								
Portlandia lucida			3	0,1	4	0,2			5	0,1				
Malletia obtusa			1	0,2										
Leda pernula									67	16,2	48	8,5	4	0,2
» minuta									3	0,4			2	0,2
Nucula tenuis			3	0,2	74	4,4			54	2,2	30	1,5	16	0,4
» tumidula			2	0,2	20	0,8								
» nucleus									1	0,1				
Natica sp.									1	0,1				
Scaphander			1	0,1										
Bullidæ									1	0,1				
Dentalium striolatum					2	0,4								
Amphilepis norvegica	2	0,2	25	0,6	4	0,2	7,5	0,25						
Amphiura (?)									7	0,1				
Ophioglypha affinis													6	0,2
» *Sarsii*									21	1,4	1	4,3	14	0,8
Brissopsis lyrifera			2	6,0	18	18,2			37	147,5	30	304,0	2	0,2
Echinocucumis typica	8	1,4												
Crustacea									3	0,1				
Gammaridæ					2	0,4								
Mysidæ (?)					14	0,6								
Neohela monstrosa			1	0,2										
Geryon tridens			1	4,4										
Crangon sp.							1,3	0,88						
Virgularia sp.					4	0,2								
Kophobelemnon stelliferum	4	15,4	5	6,5										
Spongidæ	10	3,0												
Myxine glutinosa													2	19,0
Total gr.	20,0		21,7		35,4		3,26		242,1		390,9		62,0	
Add Vermes	8,6		21,2		23,6		5,50		55,6		19,5		39,6	
In all	28,6		42,9		59,0		8,76		297,7		410,4		101,6	

Profile I b. Skagerak.	*B. Ch.*		*Transition.*						*E. Fil.*		*E. v.*		*E. v.*	
Station No.	12		1		11		3		10		9		8	
Depth in metres	91		90		68		53		41		23		15	
Temperature (Celsius)			10,0°											
No. & weight in gr. pr. 1 m²	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.
Abra alba									2	0,2	10	0,6		
— nitida	2	0,2	7		8	0,4								
Tellina fabula													10	0,6
Corbula gibba							1	0,1						
Solen pellucidus	4	1,2	1		6	1,0					6	0,2		
Venus gallina							2	0,2						
Dosinia sp.									2	1,4				
Lucina borealis	2	0,4		5,5	2	0,4								
Axinus flexuosus	2	0,2							2	0,2				
Montacuta ferruginosa	2	0,2	2											
Leda minuta	6	0,2	7				1	0,1						
Nucula nitida					4	0,2					22	5,8		
— tenuis					36	2,8	1	0,1	8	0,2	8	0.6		
Modiolaria nigra	6	51,0	3		2	17,0								
Buccinum undatum					2	3,0								
Natica pulchella					2	0,4			4	0,4				
— catena													2	1,0
— sp.	2	0,4												
Turritella terebra	14	7,2	3	3,4	16	14,8	20	18,8	2	2,2				
Scalaria trevelyana					2	0,6								
Actæon tornatilis (?)	2	0,2							2	0,2				
Cylichna cylindracea			7	1,0										
— sp.	2	0,2									2	0,2		
Philine (?)									2	0,2				
Dentalium entalis	2	2,0	2	0,5	2	0,8	3	2,2						
Chiton sp.											4	0,6		
Amphiura Chiajei	8	3,2	+	340,0	8	4,0	25	311,5						
— *filiformis*			∞		14	2,0	500		124	15,0	2	0,4		
Ophioglypha albida			2	0,1					4	0,8				
— texturata			1	2,7										
Brissopsis lyrifera	24	66,8	14	310,0	8	97,6	25	660,0						
Echinocardium cordatum					8	141,6	7	106,8	16	291,0	12	134,0	6	11,0
— flavescens	2	19,6	10	117,5										
Cucumaria pentactes					20	18,4	7	4,0	2	2,0				
— sp.			2	1,2										
Synapta inhærens							Frgm.	0,7						
Gammaridæ	8	0,4	3	0,2	4	0,4			2	0,2				
Diastylis	10	0,4	50	2,6	68	1,8			6	0,2				
Moera Loveni							7	0,7						
Crangon Allmani							1	0,1						
Cerianthus	14	4,8			10	2,4								
Actiniidæ					2	0,4								
Ascidiæ	2	0,8												
Total gr.	159,4		784,7		310,0		1105,3		314,2		142,4		12,6	
Add Vermes	22,4		29,6		37,0		51,7		6,8		2,8		0,2	
In all	181,8		814,3		347,0		1157,0		321,0		145,2		12,8	

Profile II a. S. of Drøbak. *Al. P.* *Al. P.* *Al. P.* *Al. P.*

Station No.	38		5		13		4	
Depth in metres	320–328		280		200		138–1	
Temperature (Celsius)	6,5 °		6,1 °		6,2 °		6,2 °	
No. & weight in gr. pr. 1 m²	A.	V.	A.	V.	A.	V.	A.	V.
Abra nitida								
» longicallis	2	1,0						
Arcinella plicata								
Mya sp. juv.								
Corbula gibba	2	0,2						
Neæra sp.	4[1]	0,2	2[1]	0,2				
Thracia sp.								
Venus ovata								
Lucina borealis								
Astarte sulcata								
Cardium minimum								
Axinus flexuosus	64	3,2	60	3,4	22	1,4	88	3
Montacuta ferruginosa								
Portlandia lucida	2	0,2	10	0,4	2	0,2		
» tenuis								
Arca pectunculoides							2	0
Kelliella miliaris	2	0,2						
Leda pernula								
Nucula tenuis								
» nucleus								
» *sulcata*							2	0
» *tumidula*							16	0
Lima gwyni								
» Loscombii								
Pecten vitreus	34	2,4	16	0,6	8	0,4	2	0
» septemradiatus juv.							2	0
» similis								
Aporrhais pes pelecani								
Turritella terebra								
Eulima intermedia								
» stenostoma	2	0,2						
Bullidæ	2	0,2					2	0
Siphonentalis tetragona	2	0,2					10	0
Dentalium striolatum			8	1,4			10	1
» entalis								
Amphilepis norvegica	70	3,6	46	2,0	4	0,4	2	0
Amphiura Chiajei								
» *filiformis*								
Ophioglypha Sarsii								
» affinis								
Ophiothrix fragilis								
Astropecten Andromeda					2	3,2		
Brissopsis lyrifera			6	1,6	2	0,4	10	0
Echinocardium cordatum								
» *flavescens*								
Cucumaria sp.								
Crustacea	8	0,6	2	0,2				
Munida rugosa								
Calocaris M'Andreæ								
Eiconaxius cironatus	2	3,6						
Virgularia sp.							2	0
Pennatula phosphorea								
Ascidiæ					2	8,6		
Spongidæ								
Kophobelemnon stelliferum								
Foraminifera							22	0
Myxine glutinosa								
Total gr.	15,8		9,8		14,6		9,2	
Add Vermes	10,4[8]		2,6		3,0		14,4	
In all	26,2		12,4		17,6		23,6	

[1]) Neæra obesa. — [2]) Neæra rostrata. — [3]) Neæra costella
[8]) Chætoderma nitidulum 2 — 0,2 gr. — [9]) Chætoderma nitidulum 2 –

?.	*Al. P.*		*Al. P.*		*B. Ch. S?*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch.*		*B. Ch. Fil*	
	39		11		45		3		49		10		40		32		35		43		2		31		42	
50	120		98		77		74		74		70		65		46		41		37		29		28		24–30	
	6,3 °				7,1 °		6,2 °		6,5 °		7,2 °		6,5 °		5,8 °		8,0 °		6,5 °		6,5 °		6,5 °		9,6 °	
.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.
			5	0,5	6	0,8					2	0,2			2	0,4					2	0,4	2	0,4		
											1	0,1														
																					2	0,2				
							4	0,4											2	0,4	10	0,6				
	4[2]	0,6			3[3]	0,3	4[4]	0,6			1[5]	0,1	4[2]	0,8	2[5]	0,2			2[6]	1,0						
																					2	0,2				
					3	1,1																				
																									4	0,8
					1	2,2											8	12,0								
	2	0,2					12	0,8			1	0,1	2	0,2			14	0,8			2	0,4	2	0,2		
,4	14	0,6	20	1,0	2	0,1	8	0,2			2	0,1	4	0,2							4	0,4	2	0,2	2	0,2
																									2	0,2
	2	0,2																								
					3	0,2																				
,2																	2	0,2								
					3	1,8																				
					1	0,5			2	0,4	1	0,3														
									4	0,8															2	0,4
,4					13	6,5	12	1,6	34	9,4	19	6,4	12	4,2	28	6,8	12	1,4	6	2,0			18	10,6		
,8	6	0,4	40	2,0																						
					1	0,3					2	0,7					4	0,2			2	0,4	4	2,6		
																									4	2,2
,2	2	0,2																								
4													2	0,4												
																	2	0,4								
																					4	19,0				
									8	1,6									4	0,4	46	14,0	18	5,0		
											1	0,1														
					1	0,1																				
,2			5	0,5	1	0,1											4	0,2								
,4	8	0,4					2	0,4			1	0,2														
,8					4	1,0	2	0,2	2	1,0			2	0,2	2	0,4							10	1,4		
					6	1,1											20	5,8					2	0,2	12	5,0
,2			15	0,5	2	0,1	24	1,2			13	0,4	16	0,6	14	0,4	6	0,4					10	0,4		
					36	3,8			14	3,6	15	5,7	16	2,8	26	5,0	18	5,2	274	58,4	78	18,4	214	38,0	20	3,6
					2	0,1			4	0,4									10	1,0			2	0,4	18	1,4
					1	0,1																				
											1	0,1														
											1	1,4														
																									27)	0,4
,6	8	80,4	25	6,0	5	25,6	14	9,6	4	67,2	3	5,7	4	0,6	16	117,4	38	71,0	6	302,4	10	7,6	4	8,0	10	76,8
					3	3,6													10	13,0						
					6	1,0																				
	2	0,2	5	0,5	4	0,3			2	0,2	8	0,6	12	0,6	4	0,2			2	0,2	2	1,0				
							2	3,0									2	0,6								
	4	0,8	10	3,0	1	1,0	10	3,4	14	14,8	7	6,0	14	6,2	2	3,6	6	2,2								
	2	2,2																								
,2													2	1,2												
																			2	2,0						
					2	1,5	16	90,4			4	13,0	8	25,6			∞	56,4	8	6,0	12	3,2	12	4,8	4	4,8
					Frgm.	3,6																				
											1	0,7			2	4,2										
,4	32	0,4									2	0,2					6	0,2			28	0,6				
											1	11,2														
	86,6		14,0		56,8		111,8		99,4		53,1		43,8		138,6		157,0		386,8		66,4		72,2		95,8	
	8,6		9,0		10,1 [9])		58,4		79,0 [10])		5,4		5,8 [11])		4,8		13,8		46,2		5,0		22,2		9,2 [12])	
	95,2		23,0		66,9		170,2		178,4		58,5		49,6		143,4		170,8		433,0		71,4		94,4		105,0	

ta. — [4]) Neæra rostrata 2 — 0,4 gr. N. abreviata 2 — 0,2 gr. — [5]) Neæra abreviata. — [6]) Neæra cuspidata. — [7]) Astropecten Mülleri - 0,1 gr. — [10]) Chætoderma nitidulum 2 — 0,2 gr. — [11]) Chætoderma nitidulum 2 — 0,2 gr. — [12]) Chætoderma nitidulum 4 — 0,4 gr.

Profile II b. S. of Drøbak.

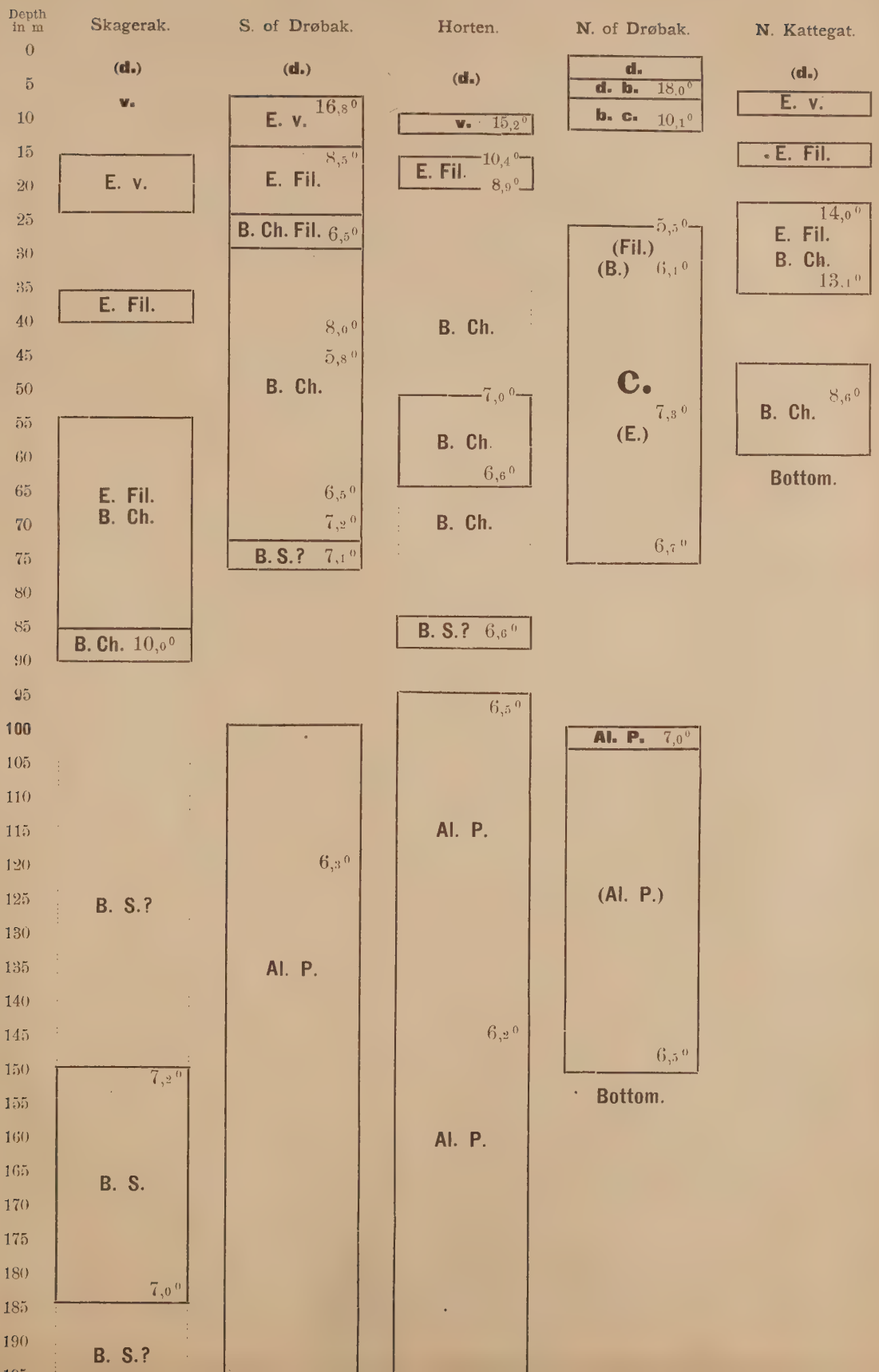
	E. Fil.		*E. Fil.*		*E. Fil.*		*E. Fil.*		*E. Fil.*		*E. Fil.*		*E. v.*		*E. v.*		*E. v.*		*E. r.*		*v.*		*d.*	
Station No.	47		41		12 a		12 b		1		34		37		48		9		44		50		51		33	
Depth in metres	24		21		17		14		14		10		10		14		13		10		9		8		4	
Temperature (Celsius)									8,5°				15,2°						13,6°		16,6°		16,8°			
No. & weight in gr. pr. 1 m² ..	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.	A.	V.
Abra alba																					14	2,6	6	0,4		
» nitida									24	0,8	6	0,4	18	0,8	6	0,6										
Macoma baltica																	4	0,2								
Tellina fabula															2	0,2					2	0,2				
Mya sp. juv.											2	0,2	2	0,2			2	0,2			10	0,4				
Corbula gibba	2	0,2			12	1,0	1	0,1	8	0,6	8	0,4	52	2,8	6	0,4					16	2,2	28	0,8		
Tracia sp.			2	0,6																						
Solen pellucidus	8	1,2									2	0,2							2	0,6			2	0,4		
Mactra subtruncata																							10	0,4		
Venus gallina															2	1,4	2	8,0			4	2,6				
» ovata							2	0,7																		
Astarte Banksii			2	0,8																						
» sulcata			2	1,8			2	1,0																		
Cyprina islandica juv.													4	1,0												
Cardium minimum					6	0,4																				
» fasciatum							3	0,4	2	0,2			4	0,2			2	0,2							2	0,2
» exiguum																									10	0,2
Axinus flexuosus	2	0,2							6	0,4					4	0,2										
Montacuta ferruginosa																					2	0,2				
Nucula nitida	4	0,4					1	0,1																		
Modiolaria marmorata									2	0,2																
Nassa reticulata													2	0,2	2	0,2	2	5,4	2	0,2	4	3,2			2	1,2
» pygmæa																							2	0,4		
Natica pulchella					4	1,2	1	0,2							2	0,6	2	0,6								
Aporrhais pes pelecani									16	66,0	8	15,4	2	10,2			2	13,0	4	5,6	4	13,6	6	10,8		
Lacuna sp.																									2	0,2
Turritella terebra	12	6,2							6	7,4																
Philine sp.	2	0,2	2	0,2					6	0,4	16	0,4			2	0,2			2	0,2	20	1,4	24	0,8		
Acera bullata											40	0,8	4	0,2	12	0,4					6	0,4				
Dentalium entalis	2	1,0																								
Chiton sp.			12	0,4	2	0,2	22	1,7																		
Amphilepis norvegica			2	0,2																						
Amphiura Chiajei			4	0,6																						
» *filiformis*	320	47,6	114	7,8	234	20,4	1	0,1	8	1,0	18	1,4	4	0,6												
Ophioglypha albida											4	0,2														
» affinis																							2	0,2		
» sp. juv.									6	0,2																
Astropecten Mülleri			2	1,4																						
Brissopsis lyrifera	2	13,4																								
Echinocardium cordatum	12	48,0	6	5,6	16	14,6	3	2,3	2	0,6	6	3,4			38	172,6					12	15,6				
Echinus miliaris											6	0,4														
Echinocyamus pusillus							1	0,1									2	0,2								
Cucumaria pentactes					2	0,6																				
Gammaridæ	6	0,4	2	0,2	10	0,2			18	0,4	14	0,2	4	0,2	6	0,4	16	0,4			8	0,4	6	0,4	2	0,2
Mysidæ																									4	0,1
Eupagurus sp.	4	0,6			4	0,8			4	3,0																
Carcinus mænas juv.											2	0,4														
Portunus depurator juv.																	2	0,4								
Edwardsia sp.			2	0,2	4	0,2	6	0,2	2	0,2	4	0,2	4	0,4	6	0,4										
Ascidiæ			4	4,8	8	13,0	2	17,2																		
Total gr.	119,4		24,6		52,6		24,1		81,4		24,0		16,8		177,6		28,6		6,6		42,8		14,6		2,4	
Add Vermes	0,6		4,0		3,2		4,5		2,4		2,2		3,0		1,6		0,2		0,6		2,4		3,2		2,1	
In all	120,0		28,6		55,8		28,6		83,8		26,2		19,8		179,2		28,8		7,2		45,2		17,8		4,8	

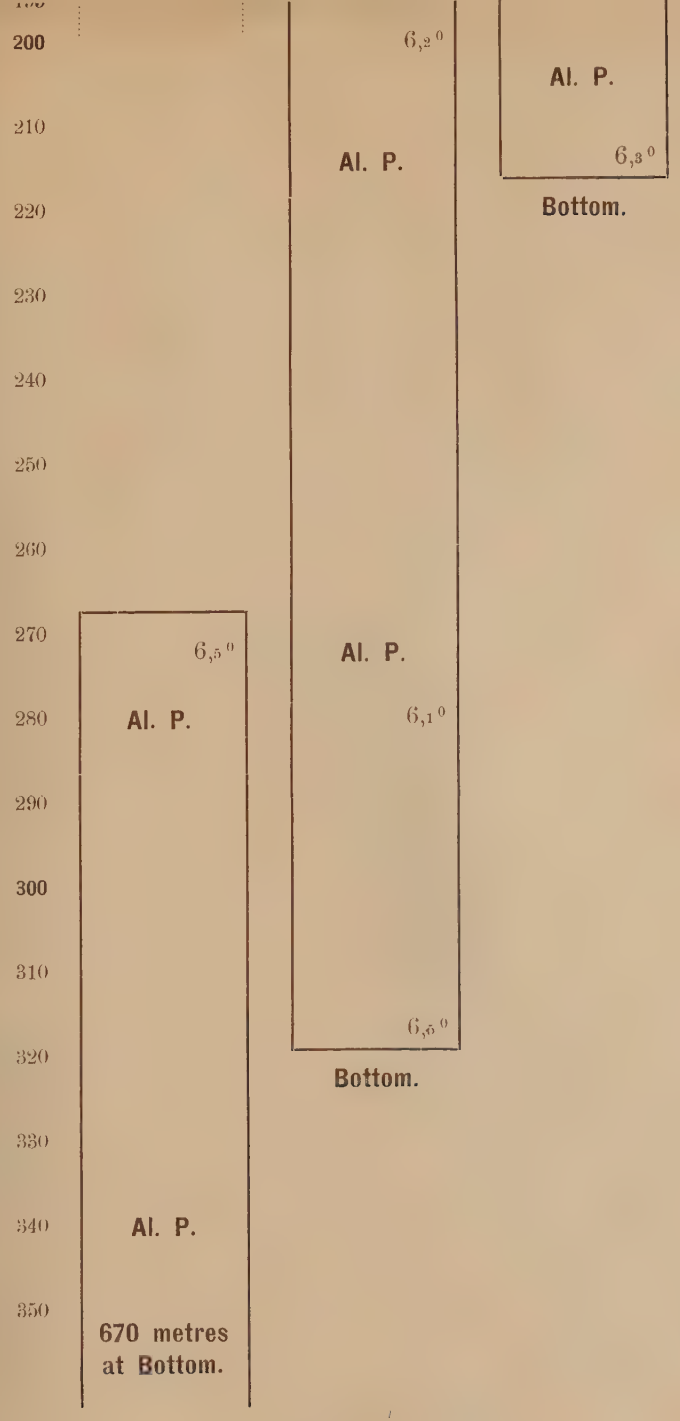
Profile III. N. of Drøbak. (*Al. P.*) *Al. P.* — *C.* with traces of *E.* — *B.* *Fil.* — *b. c.* — *b. c.* — *b. c.* — *b. d.* — *d.*

Station No.	17	14	23	25	28	22	26	29	21	18	27	15 & 16	19	20
Depth in metres	150	98	73	72	54	39	36	29	24	12	10	7	6	0,3
Temperature (Celsius)	6,5°	7,0°	6,7°	6,8°	7,3°	6,1°		6,4°	5,5°	10,2°		18,0°		
No. & weight in gr. pr. 1 m²	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.	A. V.
Abra alba									2 1,0	12 3,0	120 5,4	70 3,6	94 10,0	
» nitida			62 8,4	16 2,6			10 1,4	8 0,8	16 2,4	24 2,8				
Macoma calcarea			62 181,0	66 222,4	28 38,0		62 83,0	8 7,2	6 2,4	14 1,6	18 1,0	5 0,8		
» *baltica*													46 20,4	36 12,8
Saxicava sp.					2 1,4									
Mya truncata				2 3,6					2 7,6		6 1,2			
» (arenaria?)												7 0,8		2 0,2
Corbula gibba					2 0,2				4 0,2	14 0,8	160 8,6	11 0,3	4 0,2	
Solen pellucidus										6 3,2	6 0,6	1 0,1		
Mactra sp										2 0,2				
Astarte Banksii						4 0,2		2 4,2	4 0,2					
» sulcata					2 1,0	2 0,4								
Cyprina islandica									4 0,4	20 2,0	4 2,0	16 810,0		
Cardium fasciatum									2 0,4	10 0,4	94 2,6			
» sp.														2 0,2
Axinus flexuosus		98 2,8	166 6,0	190 7,6	36 1,8	34 1,8	4 0,4	8 0,4						
Montacuta sp.										4 0,2				
Portlandia tenuis				2 0,2										
Leda pernula		4 2,0												
Nucula tenuis		2 0,2	36 3,4	20 2,4	72 5,8	80 5,2	26 3,4	42 4,2	140 8,4	26 1,4				
Modiola sp.							2 0,2							
Mytilus edulis												61 1498,6		
Pecten vitreus		2 0,2												
» septemradiatus			4 5,8	2 1,8	8 22,0									
Nassa reticulata											22 6,8	7 4,4	16 6,8	
Aporrhais pes pelecani										2 4,0	2 5,4			
Littorina littorea														40 39,4
Cylichna sp.											2 0,2			
Dentalium entalis					4 2,2									
Amphilepis norvegica								2 0,4						
Amphiura filiformis									16 4,6					
Ophioglypha albida										12 1,4	4 0,2			
» robusta					2 0,2		6 0,2	14 0,4						
» affinis					10 0,4			8 0,2		2 0,2				
» sp.													4 0,2	
Asterias rubens													4 28,2	
Brissopsis lyrifera								2 19,4						
Echinocardium cordatum					2 20,4									
Echinus miliaris													20 46,4	
Diptera-Larvæ													2 0,2	2 0,2
Gammaridæ		4 0,2			4 0,2							1 0,1		
Diastylis sp.					4 0,2									
Tanaidæ					8 0,4									
Cerianthus sp.					2 0,6			4 1,6	2 0,4					
Ascidiæ					12 10,0									
Spongidæ				2 2,0										
Total gr.	0,0	5,4	204,6	242,6	104,8	7,6	88,6	38,8	28,0	21,2	34,0	2318,7	112,4	52,8
Add Vermes	0,1	11,8	13,8	21,8[1]	19,2[2]	13,6	39,6	27,8[3]	26,2	12,6	15,4	4,7	2,6	0,2
In all	0,1	17,2	218,4	264,4	124,0	21,2	128,2	66,6	54,2	33,8	49,4	2323,4	115,0	53,0

[1]) Chætoderma nitidulum 2 — 0,2 gr. [2]) Chætoderma nitidulum 4 — 0,2 gr. [3]) Chætoderma nitidulum 6 — 04 gr.

The 5 Profiles compared.




200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
6,2 0
Al. P.
Al. P.
6,3 0
Bottom.
6,5 0
Al. P.
Al. P.
6,1 0
6,5 0
Bottom.
Al. P.
670 metres
at Bottom.

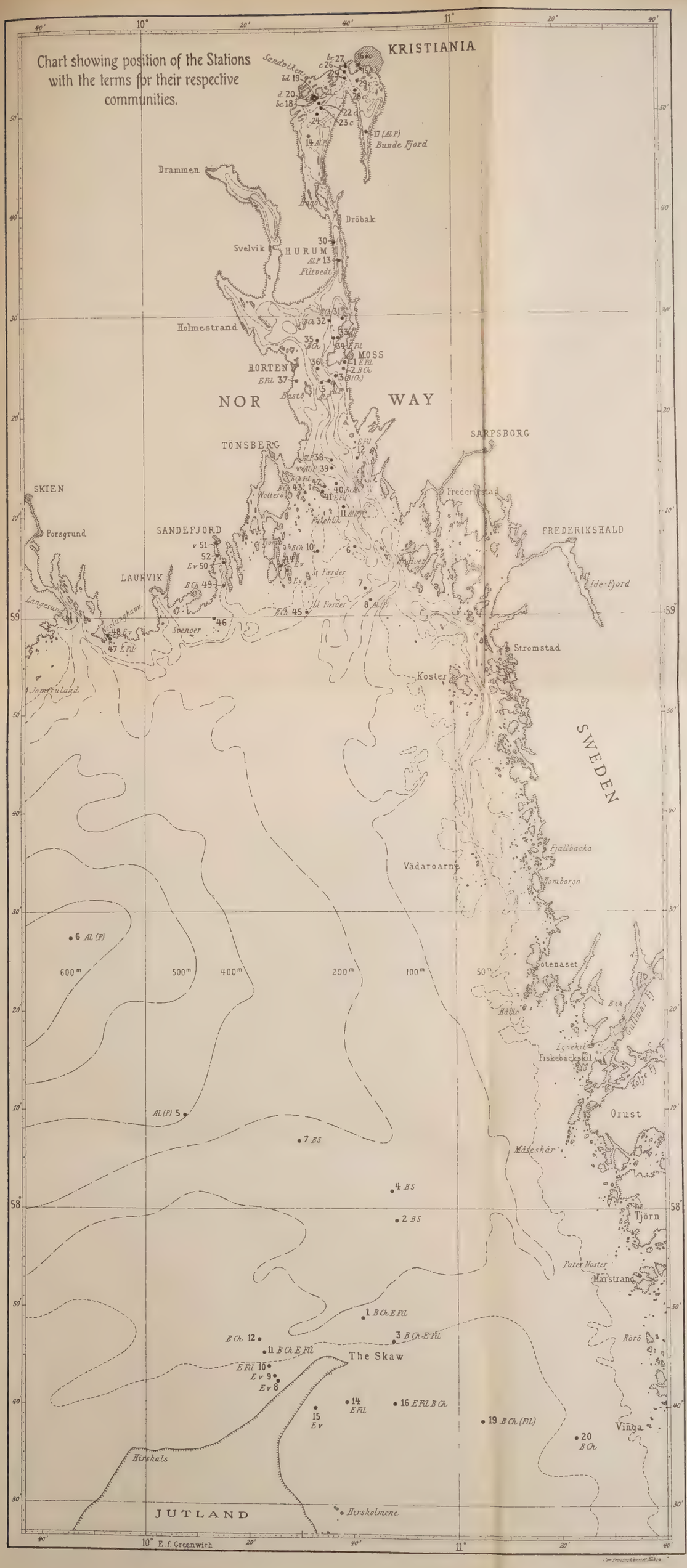


Chart showing position of the Stations with the terms for their respective communities.
KRISTIANIA
Sandviken
Bunde Fjord
Drammen
Drøbak
Svelvik
HURUM
Filtvedt
Holmestrand
HORTEN
MOSS
Basto
NOR
WAY
TÖNSBERG
SARPSBORG
SKIEN
Porsgrund
SANDEFJORD
Notterö
Fredrikstad
FREDERIKSHALD
LARVIK
Langesund
Svenger
Stromstad
Koster
Jomfruland
SWEDEN
Ide-Fjord
Fjällbacka
Vädaroarne
Hornborgo
Hätlo
Fiskebäckskil
Orust
Måseskär
Tjörn
Pater Noster
Marstrand
Rörö
The Skaw
Vinga
Hirshals
JUTLAND
Hirsholmene
600m
500m
400m
200m
100m
50m
10° E.f. Greenwich
11°

A Preliminary Result of the Investigations on the Valuation of the Sea.

By C. G. Joh. Petersen.

When we consider, that the modern — or rather quite recent — investigations which I have called Valuation Investigations date back but some few years, and that it has been necessary to invent entirely new apparatus for the study of marine bottom fauna, it will readily be recognised that these investigations are as yet only in their infancy, and far from being completed. We still lack figures for the annual production of the various species of animals in different waters, and in many cases it may be that such figures will be difficult to procure at all; others have, however, already been found, especially as regards the Kattegat. True, these figures have been arrived at by different means, and may thus be of unequal value; nevertheless it is interesting to compare them, for with all their deficiencies they yet serve to give a good idea as to the aim of the whole series of investigations. By way of example, the figures for a single water, the Kattegat, will be found schematically arranged in the accompanying diagram, p. 33.

The diagram is divived into sections, the area of each corresponding to the weight of animals or plants which it represents.

The large rectangle at the base indicates that the wet eel-grass (*Zostera marina*) in the whole of Denmark in summer amounts to 24,000,000 tons. We know that the annual production of this plant is twice that amount, but we do not know what quantity of its leaves is deposited in the Kattegat, there to serve as nourishment for the bottom fauna. In addition to the *Zostera*, there are a number of other plants (*algæ*) in the Kattegat, the amount of which is likewise unknown. For the present, I have had to take the entire amount of *Zostera* in Danish waters as basis for comparison with the other figures for the Kattegat.

Of useless animals — i. e. those of no value either for human consumption or as food for the fish — the valuations give about 5,000,000 tons in the Kattegat, as indicated by the next rectangle; to this category belong especially the large thick-shelled bivalve *Cyprina islandica*, also known in Denmark as »Molboøsters« and *Echinocardium* and *Brissopsis;* we have never found full-grown specimens of these in the stomach of any fish.

The narrow rectangle above this represents 1,000,000 tons of useful animals, which serve as food for the fish; this class consists mainly of small bivalves and small annelids.

These 1,000,000 tons are utilised in various ways in the economy of the Kattegat.

According to the International Fishery Statistics for 1910, the last published up to date, about 5,000 tons of plaice and other flatfish of similar habits are taken annually in the Kattegat; at the upper left-hand side of the diagram will be found a small rectangle indicating this amount. Farther to the right in the diagram will be seen another small figure corresponding to the 6,000 tons of cod and other gadoids of somewhat similar habits of life annually taken.

If we now suppose, as I have reason to believe may be the case, that the plaice devours ten times its own weight per year, then this fish alone will account for 50,000 tons of the useful animals; *vide* arrow on left. The cod live for the most part on large crustaceans, large gastropods and large annelids *e. g. Aphrodite* as well as small fish. The gastropods, crustaceans, and annelids and similar animals amounted, according to the valuations, to about 50,000 tons (*vide* diagram) so that if these likewise devour ten times their own weight annually, they would utilise half the amount of useful animals, or 500,000 tons. I have no figures for the weight of small fish additionally devoured by the cod, but suppose 10,000 tons; these would then again be supposed to devour 100,000 tons of useful animals.

Among the detrimentals, which devour useful animals but are themselves valueless as food for fish, may be mentioned the starfish (*Asteridæ*); these amounted, according to the valuations, to 25,000 tons. They live partly on useful animals, say 200,000 tons, partly useless creatures (*vide* diagram). We have then but 150,000 tons of useful animals remaining; among these also, however, there are various small predatory creatures which take their share of the food, so that there would not seem to be any great abundance of thus.

In the right upper corner of the diagram 7,000 tons herring are noted, this figure including also other fish living for the most part on plankton in the water itself, and thus of no importance to the bottom fauna; some of these are, however, devoured by cod.

We should, of course, instead of the stock of useful and useless animals, have taken the annual production of same; this is, however, unknown. Still, since the useful animals are generally small and of rapid growth, they may perhaps be supposed to double their numbers once or twice a year.

In calculating the numbers of *Aphrodite aculeata* as part of the food of the cod, a single very high figure in the valuations has been disregarded, as I do not know whether it should really be taken as representative of the stock; had this figure been included, then the diagram would have shown that the stock of useful animals was insufficient to feed all the predatory ones, which is a further reason to credit the useful animals with a high rate of production.

We have seen that it takes 10 kg of useful animals to produce 1 kg of plaice, while cod require 100 kg, on account of their feeding on them, so to speak, at second hand. It would thus be far more advantageous to have plaice alone.

Since however, the great predatory crustaceans and gastropods exist in the Kattegat, it is as well, after all, that the cod are there to keep their numbers down.

These figures, though but approximate as yet, give nevertheless a distinct idea of the metabolism in the Kattegat; they show in particular, how infinitesimal a fraction of the whole is utilised in human consumption in the shape of fish. If in addition to these, the useful portion of the bottom fauna, oysters, mussels etc. could be included to any great extent, much would be gained indeed; a direct exploitation of the plant growth itself would be most advantageous of all.

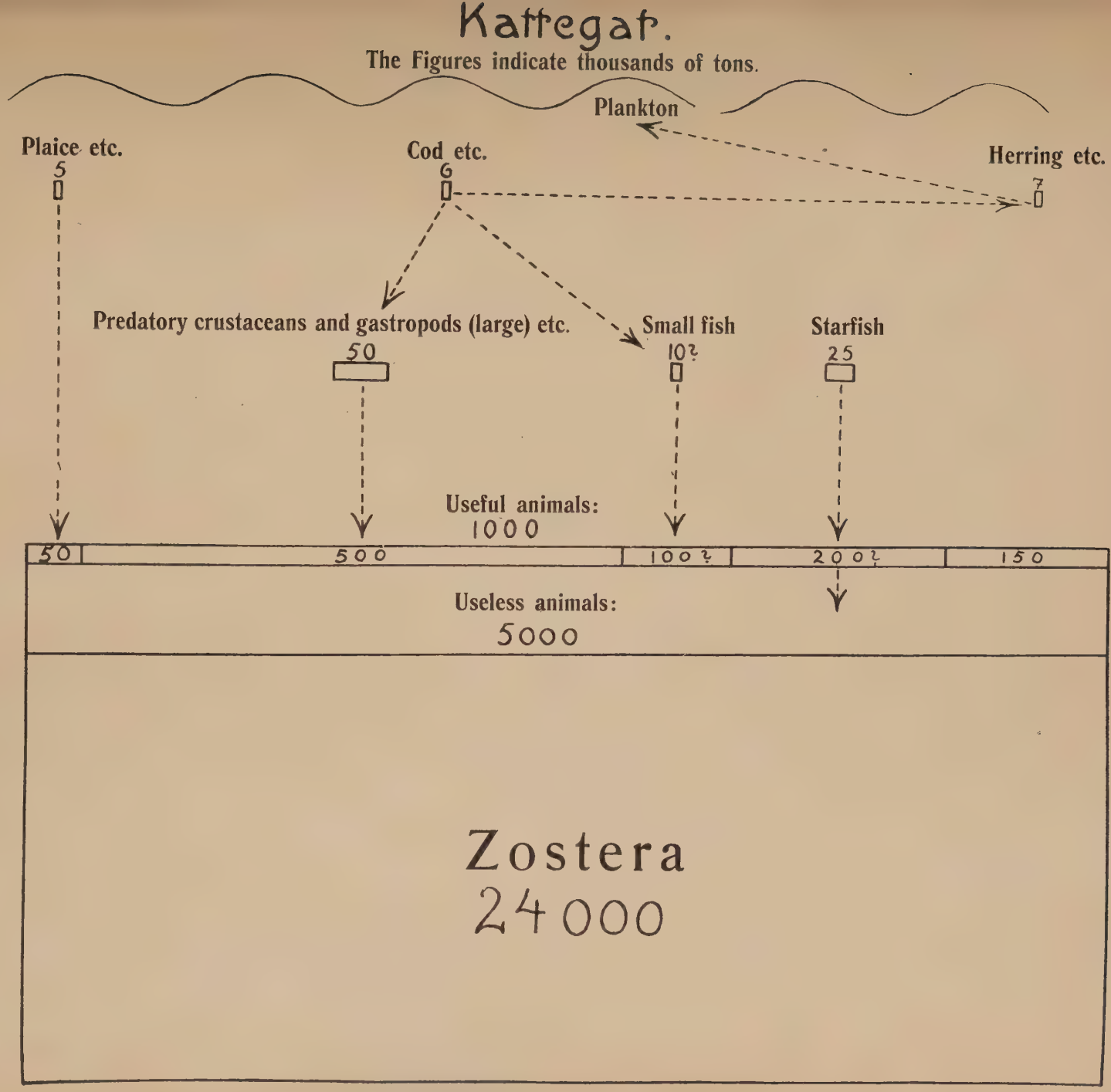
In other countries, there seems to be a better idea of thus husbanding the resources of the sea bottom in the shape of peaceable creatures; in Holland for instance between 20 and 30,000 tons of edible mussels (Pælemuslinger) are taken yearly in the small coastal waters to the south, inside the reefs (not in the Zuyder Zee) a weight exceeding the total of our whole yield of fish from the Kattegat. These small Dutch waters probably make up an area inferior to that of the Limfjord alone. It is a pity that the exaggerated fear of mussels as a dangerous article of food should be so widely entertained in Denmark. I myself, as well as the crew of the »Sallingsund« never lose an opportunity of enjoying such a thoroughly excellent dish, provided the animals are taken in a clean water, not too still. Up to the present, not a single death in Denmark has been ascribed with certainty to the eating of mussels.

And turning to the land, we may well believe that the soil of Denmark itself yielded but little in the way of food for man until man himself began to change the nature of the land to his own needs, cultivating plants for his own consumption, and keeping a stock of animals which could be nourished upon such plants as he did not directly need.

A very similar method of proceeding might be adopted with regard to the sea bottom, especially in the smaller waters, and this has, moreover, already been done. In Japan, for instance, twigs are stuck into the sea bottom, where they become covered with a growth of algæ, which are of great importance to the Japanese, who use great quantities both for human consumption and industrial purposes. On the coasts of Ireland, stones are laid down on sandy bottom for the same purpose. In Vejle Fjord, branches are set in the mud of the bottom, and form there the home of numbers of mussels (Pælemuslinger), which produce a far greater number of kilogrammes per 1 m^2 than any fish within the same area could produce grammes. In the Limfjord, certain areas were in 1914 cleared of useless creatures, and oyster shells strewn on the bottom during the breeding season; these shells are now covered with millions of young oysters. In all these cases, the fauna of the level bottom has been converted into a useful epifauna (*vide* previous Reports).

How far this improvement of the sea bottom can be carried, the future will show. One thing, however, is certain; that these investigations have already brough about the elucidation and comprehension of a number of questions previously not understood, and furnished information indispensable to a proper appreciation of the value of the sea about our coasts, and the adequate treatment of the

same. The foregoing is but an isolated example from a single water; analogous conditions are, however, everywhere existent, though possibly not with so very unfavourable proportion between producers and consumers. It has long been a known fact that carp ponds have, even without artificial feeding, given a yield of fish per hectare several times greater than that of the Kattegat.


Kattegat.
The Figures indicate thousands of tons.
Plankton
Plaice etc.
5
Cod etc.
6
Herring etc.
7
Predatory crustaceans and gastropods (large) etc.
50
Small fish
10?
Starfish
25
Useful animals:
1000
50
500
100?
200?
150
Useless animals:
5000
Zostera
24000

Errata in the Appendix to Report XXI.

Page 17, under Station No. 4: Dystialis, read: Diastylis.
— 35, — — - 1 c: calcarea, read: baltica.

Station Nr. 3 in the Kattegat (*vide* chart) is not mentioned in the valuation lists, the bottom being so stony as to render quantitative valuation impossible.

C. G. Joh. Petersen: Om de skalbærende Molluskers Udbredningsforhold i de danske Have indenfor Skagen 1888. 8°. 1162 pg. 2 Kort.

Det videnskabelige Udbytte af Kanonbaaden »Hauch«s Togter i de danske Have indenfor Skagen. 1893. 4°. 464 pg. Atlas i folio.

Indhold: Echinodermata (Petersen), Diatomeer (Cleve), Undersøgelse af nogle Bundprøver (Rørdam), Mollusca (Petersen), Cephalopoda (Posselt), Crustacea malacostraca (Meinert), Hydrografi (Rørdam), Polyzoa (Levinsen), Ascidiæ simplices (Traustedt), Annulata, Hydroidæ, Anthozoa, Porifera (Levinsen), Nogle alm. Resultater (General Results. Engl.) (Petersen).

C. F. Drechsel: Oversigt over vore Saltvandsfiskerier med Kort og Planer. 1890. 4°, 100 pg. Med et Tillæg: »Om Naturforholdene indenfor Skagen« af *C. G. Joh. Petersen*. Med Kort. 4°. 46 pg.

Fiskeri-Beretning for 1888—89, 89—90, 90—91, 91—92, 92—93, 93—94, 94—95 95—96, 96—97, 97—98, 98—99, 99—1900, 1900—01, 1901—02, 1902—03, 1903—04, 1904—05, 1905—06, 1906—07, 1907—08. 1908. 1909.

Beretninger fra den danske biologiske Station findes paa dansk publicerede i de tilsvarende Fiskeri-Beretninger.

I. Fiskenes biologiske Forhold i Holbæk Fjord. 1890—91. 63 pg. Med et Kort.
II. Om vore Kutlingers *(Gobius)* Æg og Ynglemaade. 1892. 9 pg. Med 2 Tavler.
II. On the Eggs and Breeding of our Gobiidæ. 1892. 9 pg. Two Plates.
III. Det pelagiske Liv i Fænø Sund etc. 1893. 38 pg. Tabeller.
III. The Pelagic Life in Fænø Sound etc. 1893. 38 pg. Tables.
IV. Om vore Flynderfiskes Biologi og om vore Flynderfiskeriers Aftagen. 1894. 146 pg. 2 Tavler. 1 Kort og mange Tabeller.
IV. On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. 1894. 146 pg. 2 Plates. 1 Chart. Many Tables.
V. Den alm. Aal (*Anguilla vulgaris* T.) anlægger før sin Vandring til Havet en særlig Forplantningsdragt. 1896. 35 pg. Med 2 Tavler.
Etc. 64 pg.
V. The common Eel (*Anguilla vulgaris* T.) gets a Particular Breeding-dress before its Emigration to the Sea. 1896. 35 pg. With 2 Plates.
Etc. 64 pg.
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